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MANUAL OF INJURIES *and* DISEASES OF WAR

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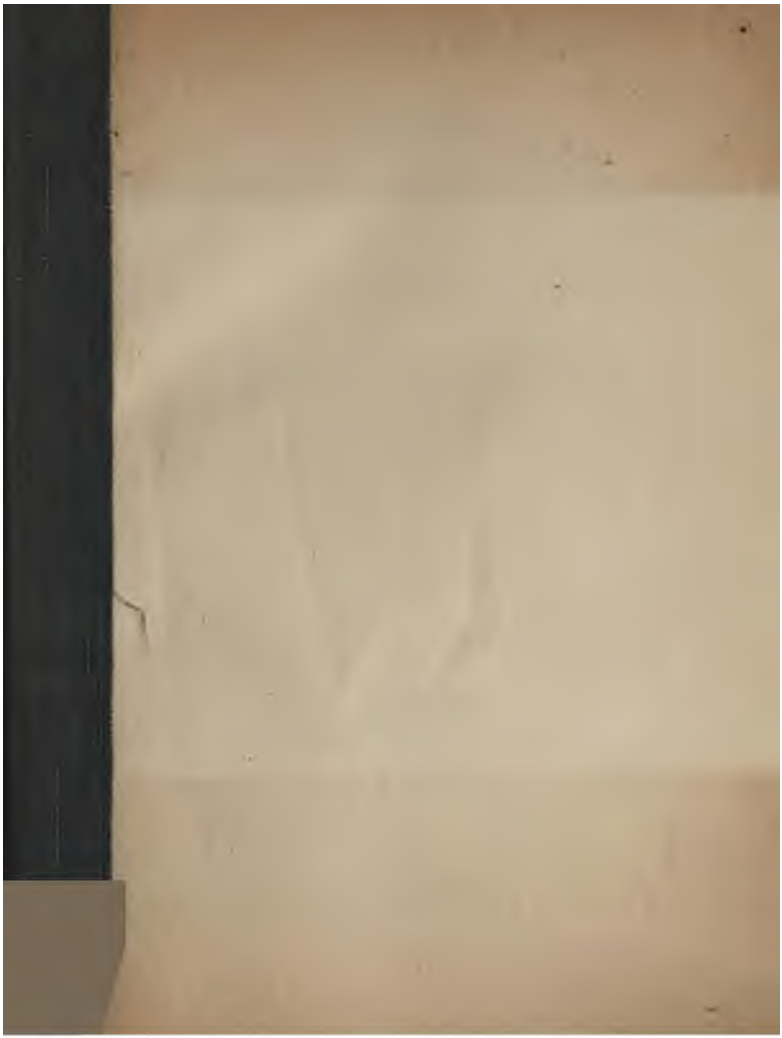

INJURIES AND DISEASES OF WAR

A MANUAL

BASED ON EXPERIENCE OF THE PRESENT CAMPAIGN IN FRANCE

JANUARY, 1918

REPRINT OF THE OFFICIAL BRITISH MANUAL
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WASHINGTON, D. C.
1918

PREFACE.

Since the "Memorandum on the Treatment of Injuries in War" was written in 1915, the Army Medical Service in France has had the experience of nearly three more years of war. The knowledge gained during this period has from time to time become known by the publication of various communications to the Royal Army Medical Corps Journal and to other medical literature; but it seems advisable to summarize now the present position of medical and surgical work, so that methods of treatment which have become generally adopted shall be easily made known to all officers of the corps.

A. T. SLOGGETT,
Lieut. General, D. G. M. S., British Armies in France.

PREFACE TO THE AMERICAN REPRINT.

Through the courtesy of the British War Office this manual is reprinted. It will furnish the medical personnel of the American Army with authentic data based on medical and surgical experience gained at the front.

W. C. GORGAS,
Surgeon General, U. S. Army.

JULY, 1918.

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Section I.—CARE OF THE WOUNDED IN THE FORWARD AREA.

The rule at the front is: "Get the wounded man to the casualty clearing station as soon as possible."

Do all you can for him at the regimental aid post or the advanced dressing station, and do it as thoroughly and as quickly as you can, so that there will be no need to disturb the patient again on his journey down.

AT THE REGIMENTAL AID POST.

The regimental aid post should be heated as far as circumstances permit. The patient here must be adequately covered and everything done to combat cold. (*See* Shock.)

Morphia.—If morphia is required it should be given in appropriate doses before the man is dressed and the man's forehead should be marked with "M" as well as an entry made on the F. M. Card. (*See* Administration of Morphia.)

The first field dressing is usually put on by a regimental orderly or a comrade and consequently it has been soiled by contact with dirty or muddy hands and has been applied to a dirty and unwashed skin.

If it has been put on by anyone but the Regimental Medical Officer, it is also likely to have been applied very tightly, with the intention of arresting hæmorrhage, and for all these reasons *it is of the utmost importance that the first field dressing should always be removed as soon as possible.* When removed, the skin surrounding the wound should be cleaned as far as circumstances admit. The gross impurities should also be removed from the surface of the wound, but no attempt should be made reach the deeper parts so as to remove foreign bodies or inject any solution. For the purpose of cleansing, pledgets of wool and forceps should be used; there is no necessity to touch the wound by hand. .

The proper splinting of large flesh wounds of the extremities, as well as of fractures, is of the greatest value.

No operations are to be done at the regimental aid post except those that cannot be delayed, but completely shattered limbs should be removed and all serious bleeding arrested before the patient is sent on. (*See* Treatment of Hæmorrhage at the Front, p. 17.)

(1) The use of general anæsthetics for the performance of such operations should be resorted to as seldom as possible. Wounded men who have been given a general anæsthetic in the forward area travel badly, and it is necessary to delay their evacuation some hours until they have sufficiently recovered to stand the journey. A previous hypodermic injection of morphia will, as a rule, permit of the rapid division of the structures still attaching the mangled limb to the body without the employmnt of a general anæsthetic. A 1-per-cent solution of novocain is a useful local anæsthetic for minor emergency operations in the forward area.

Splints required at R. A. P.—The splints usually required at the regimental aid post are:

Thomas' outfit.
Clarke's humerus splint.
Barbour's leg splint with side pieces.
Assorted flat splints.
Gooch's splinting.

IN ADVANCED DRESSING STATION.

Dressings and splints are inspected and adjusted. If it has been impossible to adequately treat the patient before arrival, it is done here, keeping in mind the same rules governing the practice as at the regimental aid post.

Preparation of dressings in forward area.—Dressings and wool should be prepared beforehand. They must not be left lying about exposed to dust and dirt.

Dressings should be cut up into suitable sizes (6″ × 6″), and may be sent up ready sterilized from the headquarters of the ambulance to the regimental aid post and advanced dressing station. This can be done in two ways:

(1) The dressings, carefully laid in layers, are boiled in a French *marmite; the excess* of water is then poured off, and an antiseptic *added if desired.*

(2) The dressings are dry sterilized in a "Helby" box (*see* fig. A). They are carried up in this and used dry, or laid carefully in a shallow marmite, and wetted with an antiseptic.

Eusol has been found an efficient and convenient antiseptic.

Technique of dressing.—It is possible, by the use of forceps, to do all dressing without touching the dressings by hand. The forceps may be flamed, or kept in a strong antiseptic solution.

FIG. A.—Helby's Box.

Made from a tea tin and a petrol tin. The petrol tin, being slightly smaller, fits within the tea tin. By perforating the opposite sides of both boxes a good imitation of a Schimmelburch's kettle is made. To make an air seal the box should be lined with lint.

Dressings can thus be removed from the marmites without soiling.

Cyanide gauze, if laid on tincture of iodine, may cause severe blistering, so that these two should not be used together. Picric acid, 1 to 3 per cent in alcohol, is very efficacious, and presents no such objection.

Small marmites will be found very convenient for storing of swabs, instruments, and infusion apparatus.

IN THE MAIN DRESSING STATION.

In stationary warfare the wounded man need not necessarily pass through this station, but can be taken straight to the casualty clearing station. If he is admitted, however, to a main dressing station, the same procedure is to be followed as at the advanced dressing station.

The Field Medical Card.—This is filled up by the medical officer who dresses the patient at the advanced dressing station. It is of the

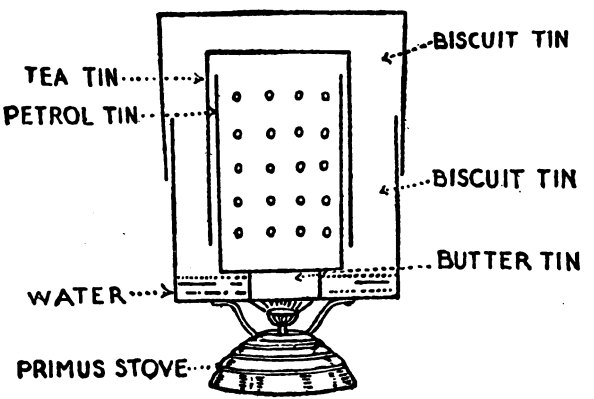

FIG. B.—Method of sterilization of dressings in the Helby box by a primus stove.

greatest importance to the wounded man that this should be done carefully. This card should always show—

(1) The stamp of the field ambulance.
(2) An *accurate* description of the injury; for example, "Comp. fracture of the skull," *not* "G.S.W. Head"; "Comp. fracture of femur," *not* "Shell wound of thigh."
(3) If the case is one requiring immediate operation, this should *be* stated, *e. g.*, "Urgent—Operation required."

(4) If an operation has been performed at the field ambulance, this should be noted accurately.
(5) If morphia has been given, the dose and time of administration should be put on the card (and a large M put on the forehead of the patient).
(6) The amount of antitetanic serum injected should be noted (and a large T marked on the wrist).
(7) The hour at which the wound was dressed.
(8) The signature of the surgeon who treated the case.

ADMINISTRATION OF MORPHIA.

If properly used, morphia is a most valuable drug. It should be administered as soon as possible after the receipt of the wound. It is beneficial only in so far as it banishes pain and distress.

By far the best method of administration is under the skin. If given by the mouth it may be vomited, and even if it is not it is slow in action. In the latter case a second dose given under the skin, because the first dose has not acted, may produce too great an effect.

The tabloid if dissolved in the mouth may act quickly, but the tabloid is often swallowed, when it will be but slowly absorbed into the system. Again it may be spat out and so produce no effect.

Morphia can be easily given under the skin by the following method:—

Every regimental and bearer officer should carry two bottles of the kind shown in the accompanying diagram.

The first is a stock solution 2½ per cent of morphia in a rubber capped bottle of the type in which anti-typhoid vaccine is now supplied. The second is a bottle with a perforated cork bearing a hypodermic syringe. The needle of the syringe projects into alcohol and is thereby kept sterile and always ready for use. When an injection is required the cork with the syringe is removed and loaded from the first bottle. A complete syringeful is equivalent to ¼ grain of morphia.

A ¼-grain dose is usually sufficient if given under the skin, but as much as ½ grain may be required. A ½-grain dose has, however, often been found to have produced too deep an effect by the time the patient has reached a casualty clearing station.

It is essential that the dose, time, and method of administration be entered on the field medical card.

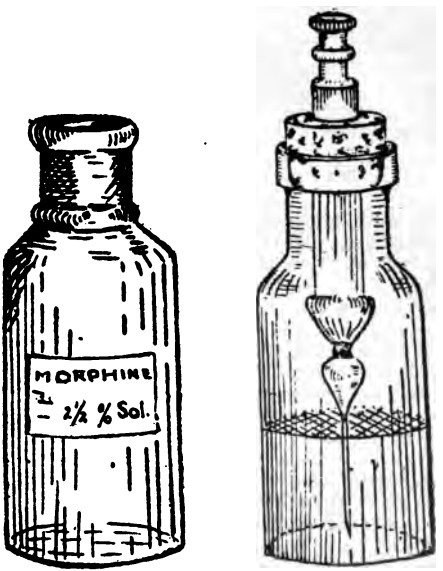

FIG. C.—Method of keeping Hypodermic Syringe ready for use.

IN THE CASUALTY CLEARING STATION.

When large numbers of wounded are arriving, arrangements are made for their reception in a suitable tent or hut, and from this they are passed on to a "walking wounded" area or a "lying wounded" area, which should be very thoroughly warmed, and *where further* arrangements have been made for dressing the *wounds*

Classification of wounded.—In these dressing rooms the patients are ultimately placed in four classes:

1st. For evacuation.
2nd. For retention in the wards.
3rd. For resuscitation.
4th. For operation.

It is the first two classes which require careful dressing on their admission, for the wounded of the third and fourth classes will both require anæsthetics in the operating theatre. The proportion of cases which should be sent to the theatre varies in proportion as there are many or few wounded, and if there are few, then at least as many as three-quarters of the whole will benefit by being placed for operation in class 4, and in this class all fractures must always be placed.

If the patient arrives on a stretcher soiled by mud or blood he should be placed upon a clean stretcher.

Removal of clothing.—Before dressing wounded men much of the clothing should be removed, so that complete access is obtained to the whole of the wounded limb or the trunk as may be required.

Removal of dressings.—If the patient is a "lying" or "stretcher" case, the boots and the trousers should, if possible, be removed before he is brought into the dressing room, so as to keep the surroundings clean. The limb should then be placed on clean jaconet or waterproof sheeting, or on a sterilized towel, and as soon as the old dressings are removed the wound should be covered with an aseptic swab while the skin around is cleansed. If the wound is very small and quite superficial, it may be only necessary to wash carefully and re-apply suitable dressings. But it is now the custom to operate on almost all wounds, of whatever size, so that most patients should be sent to the pre-operation ward in readiness to go to the operating theatre.

Evacuation of slightly wounded.—If wounded are very numerous, the slighter wounds, and especially those without fractures, are sent to special hospitals in the rear, so that the staffs of the casualty clearing stations can give all their attention to the more serious cases.

Operations on recent wounds.—It is now universally admitted that all the wounds in France and Belgium must be considered as seriously infected, and careful investigation has established that, not *only are the* ordinary pathogenic organisms present in them, but

that the tissues are also infected by the spore-bearing microbes of gas-gangrene and tetanus. Against such infections as the latter, antiseptics are of no use, and they are of but little help in the gross infections by the ordinary bacteria of suppuration. Many of the conditions of war tend to aggravate the action of bacteria, and amongst these conditions is to be specially noted the widespread crushing and devitalization caused by the missiles of the present day.

Complications of war wounds.—Such damaged tissues are quite unable to protect themselves, and in them infection rapidly extends, more especially in the torn muscles. It must also be remembered that parts of the clothing covered with mud are often driven deep into the wound, that the wounded man has very likely fallen into mud or muddy water, and that he may have been lying, even for many hours, with the injured part in a fluid containing every kind of bacteria. None of these complications are to be found in the injuries of civil life, and the bad condition of the wounded man may be aggravated still further by loss of blood, by exhaustion from days and nights under fire, by want of food, or by cold and wet; whilst, to add to all this, it may have been impossible to bring him into the casualty clearing station until a day or more has passed.

Even when there are no such complications, the wound must be regarded as badly infected, and must be treated as such; whilst, in the worst cases of lying out, gas-gangrene may be found to be already extensive when the patient arrives in the theatre.

Early operations.—Experience has shown that by far *the most important treatment is the early mechanical cleansing of the wound and the excision of all badly torn tissues under an anæsthetic.* Nothing that can be subsequently done can compensate for the omission of this, and without this the application of antiseptics is useless. If this excision is thoroughly carried out, any subsequent line of treatment is simplified, for early excision is the necessary basis for all useful methods yet devised. In the performance of such an operation, every care must be taken to avoid further contamination of the wound, and the *sterilization of gloves, towels, and instruments is essential. It is most important that the excision of skin should be as limited as possible,* and should be restricted to the removal of a very thin paring of the edge of the wound, although large incisions may be *necessary to give* free access to deeper parts. Muscle must be more *freely excised, because it* is especially liable to be the seat of anaërobic *infection, and any* muscle which neither contracts nor bleeds *should be cut away.* (*See* also Gas-gangrene.)

Removal of foreign bodies.—The removal of bits of metal, and especially of large shell fragments, should form part of every such operation, and careful search should be made in these cases for the fragments of clothing and of mud which are commonly carried in by such missiles.

In some cases the skin is the seat of a great number of slight wounds which have been caused by mud or gravel blown up by a shell or bomb, and thrown with such violence as to penetrate the skin. In such cases lumps of mud may be forced through small apertures in the skin, and are a fertile source of acute sepsis. This mud should be removed as far as possible through incisions, and the whole of the skin area involved should be painted with picric acid in spirit.

Radiography may often be necessary before an operation is begun, but when the wound is very superficial, it is not necessary, and when patients are arriving in very large numbers it is not possible to examine them all with X-rays.

Antiseptics are commonly employed at the front in all operations. After washing and shaving, the skin is usually painted with a solution of iodine or picric acid, and during the operation each surgeon uses the antiseptic which he prefers. "Eusol" is the one most commonly employed.

SUTURE OF WOUNDS.

Wound suture.—It may be stated in general terms that the slighter and the less complicated the wound, the more reason there is for closing it by suture; and that the more extensive the laceration, the longer the patient has been lying out after his injury, and the more the wound is obviously contaminated, or already infected by gas-forming organisms, the more should the wound be left widely open.

It is also of the utmost importance to know whether the patient is to be retained in the casualty clearing station or whether he has to go by rail to the base, for it is quite certain that many wounds which may be safely sutured if the patient is to remain quietly in bed will do badly if he is sent a long journey by train. It appears probable that the movement of the patient and the vibration of the train cause distension by fresh oozing during the journey, and in many such cases the wound on arrival is found so painful and swollen that *the sutures have to* be immediately removed.

Primary suture.—It is, however, certain that in cases where the patient has not been wounded more than 10 or 12 hours, and where the wound is not very large and is limited to the soft tissue, "primary suture" is very advisable after a complete excision of damaged tissues, provided that the patient can be retained in the casualty clearing station.

Delayed primary suture is the closure of a wound within the first few days after its excision, and when the patient has had to be evacuated quickly, or where the cut tissues are not dry enough for closure at once, the wound should be completely sutured subsequently in suitable cases. If it is a small wound it may be closed within 24 hours, but if large or complicated by a fracture suture had better be delayed till the second or third day. The results are identical with those obtained by suture at the time of operation.

Secondary suture is the closure of a granulating wound. If it is not possible or else is inadvisable to suture a wound at the time of operation or directly afterwards, it should be closed by "secondary suture" as soon as it is in a suitable condition for the purpose, and it is most desirable that the great majority of superficial wounds should be so sutured within a week or two of their infliction.

In extensive injuries the decision to close the wound by secondary suture should be dependent on a report as to its comparative freedom from bacterial infection, but in quite small and superficial wounds this may often be dispensed with.

Treatment when the wound is not closed—Carrel's method.—If a large lacerated wound is left open, and especially if it is complicated by a fracture, the method of Carrel, combined with the use of Dakin's fluid or eusol, is generally considered to be the best to employ. This treatment can be continued on the ambulance trains quite efficiently and without disturbing the patient, and cases so treated travel well and arrive in good condition.

When wounded are very numerous, Carrel's method is difficult to carry out in every case in a casualty clearing station, because of the impossibility of obtaining a sufficient staff for the after-treatment, and in many patients with multiple wounds it is also obviously impracticable to treat all of them in this way. In wounds of the buttocks and back it is also difficult to use it in many cases.

Other methods.—If Carrel's method is not used, the wound may be treated in one of various ways.

It may be lightly packed with dry gauze, or else with gauze soaked in some antiseptic solution such as eusol or flavine, or else the bismuth, iodoform, and paraffin paste known as "B.I.P.P." may be used. One objection is that the paste materially interferes with the taking of radiographs, and another most important objection to its *unlimited* use is that *symptoms of poisoning* by either bismuth or iodoform have been observed in many patients; the bismuth causing blackened or ulcerated mouths and diarrhœa, and the iodoform producing mental symptoms with hallucinations and delirium. For these reasons it is imperative that if the "B.I.P.P." is used it must be used very sparingly. It should be rubbed into the exposed tissues and *no surplus should ever be left in the wound.* It is also unwise to dress several large wounds in the same patient with "B.I.P.P.," and if the patient is to travel *the wound should not be sutured.*

Other forms of paste containing different antiseptics have been advocated by different surgeons, and good results have been attributed to them.

Operation is more important than antiseptics.—There are many antiseptic agents which either have been or may be employed, but it must be clearly kept in mind that in recently wounded men, where infection has not had time to extend deeply into the tissues, *it is far more important to completely excise all damaged and infected tissue than to use any antiseptic.*

Antiseptics are more especially indicated when the wound is either so situated or so extensive that it is not possible to perform a complete excision, or else when it is already a day or two old before the surgeon sees it, and is therefore already deeply infected by bacteria.

TREATMENT OF HÆMORRHAGE AT THE FRONT.

Bullet wounds do not cause severe bleeding unless they happen to injure some large trunk or smash one of the larger bones. Wounds caused by fragments of shells or bombs tear larger holes in the skin and lacerate the muscles and are, therefore, more often the cause of serious bleeding.

Arrest of bleeding.—The principles of the treatment of hæmorrhage are well established, and are the same for both civil and military practice, and these principles lay down as an essential rule that *bleeding is to be arrested by pressure upon, or ligature of, the bleeding*

point itself, and *not* by constriction of the limb above or by tying the artery on the proximal side of the injury.

Tourniquet.—The systematic use of the elastic tourniquet cannot be too severely condemned. The employment of it, except as a temporary measure during an operation, usually indicates that the person employing it is quite ignorant both of how to stop bleeding properly and also of the danger to life and limb caused by the tourniquet. Its systematic use by orderlies should not be permitted, and they should be instructed that the only conditions in which they may regularly employ it are when a limb has been completely smashed or actually shot away. It may also be occasionally used as a very temporary measure of stopping bleeding whilst the patient is being carried to the regimental aid post. If an orderly has applied a tourniquet *it is the duty of the medical officer who first sees the patient to remove it at once*, and to examine the limb so as to ascertain whether there is any bleeding at all, and if there is, to employ proper measures for its arrest. Most often there is no bleeding of any importance, and in many other cases its arrest by proper means is perfectly easy.

Dangers of tourniquets.—The application of a tourniquet causes intense pain, and for this reason alone it should be rarely used. Even if applied for only an hour it greatly interferes with the nutrition of the wounded tissues, and so favours the development of the anaërobic organisms, while, *if it is left for as long as six hours the whole limb will certainly die*, as the direct result of its application.

No patient should ever be allowed to leave a field ambulance with a tourniquet on his limb, and orderlies collecting wounded should be taught how bleeding can almost invariably be arrested temporarily by a firm bandage over a wound which has been filled tightly with gauze, or by steady digital compression of a wounded vessel.

The proper way to stop bleeding.—The first step in the arrest of bleeding *at a field ambulance* or regimental aid post is to examine the wound and see if any obvious bleeding point or any definite wounded artery requires to be tied, and, if that is the case, a ligature should be applied. If the vessel is deeply situated, and the absence of sufficient light or sufficient assistance makes its ligature very difficult, it is often possible to seize the vessel with forceps which may be left on until the casualty clearing station is reached. This *arrest by "forcipressure"* can often be accomplished when the application of a ligature is difficult.

Arrest by pressure.—If there is no obvious vessel to be tied, direct pressure by plugging will usually stop hæmorrhage. In such cases, it is necessary to see exactly from where the bleeding comes, and to place the first part of the plug as near as possible on the bleeding spot. The whole wound is then filled and the limb firmly bandaged upwards, from the hand or foot as the case may be. In order to get firm pressure without constricting the limb, *the bandage should always be applied over a wooden splint* of sufficient breadth applied to the opposite side of the limb.

If bleeding has been difficult to stop, a note should always be made on the field medical card, and this should also be marked "Urgent," in large letters.

In sending such a case to the casualty clearing station, it is advisable to leave on the limb a loose tourniquet and to send an orderly with instructions to draw the ends tight if serious bleeding occurs during the journey.

Tie bleeding vessels.—At the casualty clearing station all cases of suspected hæmorrhage must be thoroughly investigated under an anæsthetic, and the bleeding vessels found and securely tied. Ligatures should, if possible, be placed both above and below the bleeding point.

Any vessel, even the largest, such as the subclavian or the femoral, may temporarily cease to bleed—usually after much blood has been lost—and in many instances this has been observed whether the artery has been completely or partially divided. In the absence of bleeding the condition of the patient and of the hand or foot of the injured side will generally indicate the damage to the vessel if the surgeon is on the lookout for such cases.

It has been found by experience during the present war that gangrene is less likely to follow on ligature of a large trunk, such as the popliteal or the axillary, if the main vein is also tied. It is, therefore, the custom to tie the main vein with a separate ligature after the bleeding artery has been secured.

Section II.—WOUND SHOCK.

Definition not known.—The condition known as shock is familiar to all. A precise definition has yet to be found, but a fall in the body temperature and in the arterial blood pressure are the most constant features.

It has both a mental and a physical side.

Causes.—Pure shock, that is a state of extreme depression of the vital functions, without apparently adequate cause, and possibly ending in death, has been met with.

On the other hand, shock as seen in war is usually the result of one or more of the following factors:—

The actual cause is some violence, usually a wound. It is predisposed to by wet and cold, lack of food, especially lack of water, want of sleep, exhaustion following extreme exertion and mental strain. It is aggravated by pain, disturbance, loss of body heat, and by hæmorrhage.

It is proportionate to the sum of the intensities of the factors producing it.

The condition caused by acute sepsis may so closely simulate shock as to be indistinguishable from it.

Shock is especially liable to ensue on the following types of injury:

Multiple wounds;
Avulsion of limbs;
Wounds with extensive laceration of muscle and comminution of bone; and
Extensive injury of the brain, thorax, or abdomen.

Clinical signs of shock.—The clinical manifestations are usually as follows:—

A rapid, small, or even imperceptible pulse;
A skin cold but sweating;
Vomiting;
Pallor or cyanosis;
A depressed body temperature; and
A low blood pressure.

The mind is often acute, but may be clouded, especially in the later stages.

Primary and secondary shock.—Shock may be (*a*) primary or (*b*) secondary.

(*a*) Primary shock comes on almost immediately after the receipt of the wound. The patient passes into a state of collapse, becomes pale, breaks out into a cold sweat, vomits, loses muscular power, and experiences thirst. At this stage the pulse rate and blood pressure may or may not show a great departure from the normal.

(*b*) Secondary shock manifests itself later. It seems in great part to be caused by pain, disturbance, and exposure to cold.

Thus a man with a fractured femur may, if he is kept quiet, properly splinted and adequately warmed, never exhibit any sign of shock, while another, with the same injury, may pass into a dangerous state of collapse if insufficiently splinted and exposed to cold.

Both (*a*) and (*b*) are greatly aggravated by loss of blood, sepsis, and mental perturbation.

Fall in alkalinity of the blood and of the blood pressure.—Recent observations show that most wounded men in a state of shock suffer in more or less degree from a reduced alkalinity of the blood. This condition is commonly known as "acidosis."

The fall in alkalinity is correlated in some way with the fall in blood pressure. It is not known in what relation they stand to one another, whether they are inter-dependent or dependent on some common factor.

Effect of operation and anæsthesia on the pressure and alkalinity of the blood.—It has also been shown that an operation on, or the administration of an anæsthetic to, a man with a reduced alkalinity of the blood is fraught with danger because it leads to a further fall in the blood pressure and in the alkalinity of the blood.

The blood sugar and the urine present no marked departure from the normal.

Conditions to be combatted in shock.—In a shocked man there are three main conditions to be combatted:—

(*a*) Loss of body heat.
(*b*) A low blood pressure.
(*c*) A decreased alkalinity of the blood.

(*a*) *Loss of body heat.*—This may be due to evaporation caused by sweating, or to a reduced production of heat within the body, *or to* insufficient or wet clothing.

(b) Fall of blood pressure.—This may be due to (1) an actual *escape of blood from* the body by bleeding; (2) to a reduction of

the volume current in the circulation, which reduction is held by some to be caused by a stagnation of blood within certain vessels, or to an escape of the fluids of the blood from the vessels.

(*c*) *Decreased alkalinity of the blood.*—The cause of the reduced alkalinity is unknown, but is attributed by some to deficient oxidation in consequence of inadequate supply of blood.

TREATMENT.

This may be conveniently divided into that to be adopted in (*a*) the forward area and (*b*) the casualty clearing station.

IN THE FORWARD AREA.

In forward area.—In the forward area arrest of bleeding, warmth, efficient splinting, relief of pain by morphia, are to be aimed at. The preservation of the body heat will tend to prevent the onset of shock or to minimise it when present.

The following points are to be observed:—

In trenches.—A blanket and ground sheet should be attached to the stretcher that is kept in the trenches or accompanies a detached party.

Suggestions for folding a blanket in a waterproof sheet for carriage in a stretcher.

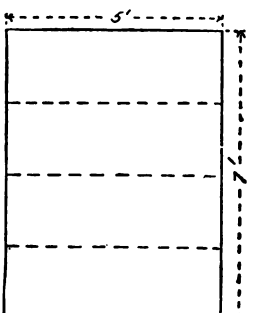

FIG. 1.—Service blanket to be folded four times at the dotted cross lines.

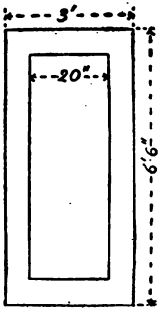

FIG. 2.—Placed lengthwise on a waterproof sheet, and again folded four times, with the edges of the sheet turned in.

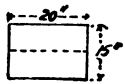

FIG. 3.—A packet the size of a stretcher pillow is thus produced, 5 lbs. in weight. This is doubled and carried in the closed stretcher in the usual way.

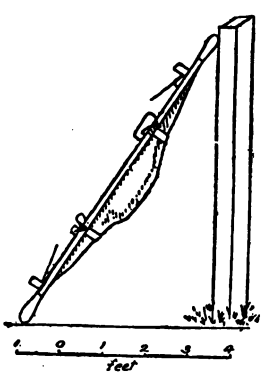

FIG. 4.—Two pieces of bandage retain the packet in the center, making a comfortable pad for the bearer's shoulder.

In aid posts.—In the aid post a warmed stretcher is to be provided, on which the patient is laid while he is being attended to. The part of the body not receiving attention should be carefully covered with a blanket.

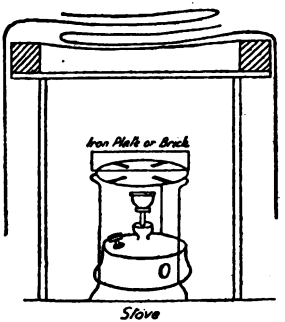

FIG. 5.—Blankets and stretcher heated ready for patient.

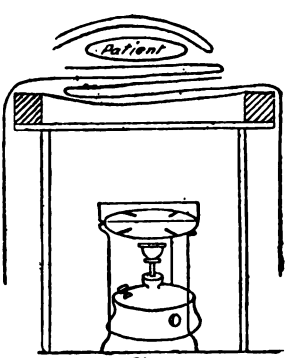

FIG. 6.—Patient heating up.

Hot drinks.—If the patient can take it, hot sweetened tea or coffee should be given, also a drachm of bicarbonate of soda in water.

Removal of clothing.—On the whole it is beneficial to remove wet clothing, but judgment is required in deciding whether or not to do so. The need is not great so long as the patient can be got warm. It may, indeed, be harmful if conducted in a cold atmosphere, both on account of the exposure and disturbance of the patient. If a long wait is anticipated clothing should be removed (*see* also Treatment of fractured femur, p. 60).

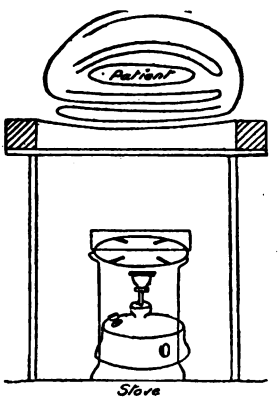

FIG. 7.—Patient ready for transport.

Hot bottles.—Before sending on the patient a hot bottle should be placed on each side of the chest so that the bottom of the bottle rests on the stretcher between the body and the arms. Another one should be placed across the groins. *They should not be placed next the skin.*

Morphia.—Morphia is best given under the skin. It is beneficial only in the relief it affords from pain and anxiety. The amount *given should* be strictly limited (a ¼ grain under the skin is usually *sufficient).*

Time should be given for it to act. Morphia given by the mouth is apt to act slowly.

At advanced dressing station.—Before being placed in an ambulance, the patient, if necessary, is again warmed up, adjustments are made in splints and bandages, hot bottles are refilled, and hot drinks again given.

Intravenous injections may be required here or at the regimental aid post (*see* Shock at C.C.S.).

AT THE CASUALTY CLEARING STATION.

Treatment at C.C.S.—If the patient is extremely ill it is best to place him on the warmed stretcher, and undress him, if thought advisable, while he is still lying on this. He will thus receive heat all the time. *After being undressed,* he can be put to bed and the electric or hot air cradle applied.

Quiet, rest and warmth, combined with alkali by the mouth, and morphia under the skin, will in many cases render the patient fit for operation.

Hæmorrhage.—In cases of hæmorrhage intravenous injections will be required. Blood transfusion (1—2 pints) is by far the best, but a solution of gum (1 pint of a 2—6 per cent. in normal saline) may be used in those cases where a donor is not available or in which the symptoms are not severe enough to warrant the use of blood.

If acidosis is suspected, an alkaline infusion (a pint of a 2—4 per cent. of sodium bicarbonate) may be given in addition to the transfusion, or the gum-bicarbonate solution may be substituted for the simple gum solution.

Hæmorrhage absent; but a failure to rally.—If the patient fails to rally although no hæmorrhage has occurred, it is best to give an alkaline infusion, followed if thought advisable by transfusion, or to give the gum-bicarbonate solution by itself. Both procedures act best if adopted just before operation.

Vomiting.—Vomiting frequently indicates a fall in the alkalinity of the blood, and if accompanied by a rapid pulse and signs of shock is itself a sufficient indication for an alkaline infusion (2 or 4 per cent. of bicarbonate of soda).

Operation—anæsthetic.—The table should be warmed and the patient exposed as little as possible. Rapidity of operation is important. Nitrous oxide and oxygen is the best general anæsthetic and

warm ether the next. It is imperative that cyanosis be avoided whatever anæsthetic is used.

Gum-bicarbonate solution.—The solution must, on no account, be subjected to sterilisation by boiling *after* the sodium bicarbonate has been added, since this causes the conversion of the bicarbonate into the strongly alkaline carbonate. Unless the solution can be obtained ready prepared and sterilised in sealed bottles, it should be made as follows: A 6 per cent. solution of gum in water is prepared and sterilised by boiling. This may be made as required or kept as a sterile stock solution. Just before use, sodium bicarbonate (which can be kept weighed out in paper packets for the purpose) is added to the cool solution in the proportion of 2 per cent. and stirred well until dissolved. A precipitate of calcium bicarbonate is formed, and must be filtered off through a wad of several thicknesses of sterile gauze into a sterile vessel. This will remove all coarse particles, and the filtrate, though milky in appearance, may be safely injected. It should be raised to the proper temperature before injection (by means of a water bath).

Section III.—TRANSFUSION OF BLOOD.

Transfusion of blood has been performed with increased frequency during the past year, and has been of the greatest use in cases of severe primary or secondary hæmorrhage, as well as in many cases of shock. The following methods are those chiefly practised at present.

(1) Transfusion by paraffin-coated glass tubes. Tubes are supplied by the Army and can also be improvised from the ampoules in use for the Carrel treatment of wounds.

(2) The blood may be mixed with citrate of soda to prevent its coagulation, and the mixture may then be injected into the vein of the recipient; the mixture should contain one half per cent. of the citrate.

(3) The blood may be drawn from the donor by a suitable syringe fitted to a cannula in the vein and then at once injected through another cannula placed in the vein of the recipient. Repeated injections are required to transfer a pint of blood.

(4) Blood corpuscles have been citrated and preserved for at least two or three weeks in a refrigerator before use.

(5) Transfusion may be done by the "direct" method through paraffined cannulæ and rubber tubes leading from the artery of the donor to the vein of the recipient.

Whatever method is adopted for transferring the blood certain precautions are necessary.

(1) The donor must be a healthy and young man and free from all evidence of diseases which can affect the blood, such as syphilis or malaria.

(2) If possible, arrangements should be made beforehand in all units where transfusion is likely to be required for agglutination tests to be tried before the operation is begun, so as to avoid the use of an incompatible blood.

(3) If these tests are not available the surgeon should wait one full minute after injecting the first ounce of blood in order to be

able to recognise the symptoms of "incompatibilities." These symptoms are summarised by Colonel Cabot as follows:—

(*a*) Pain in the lumbar region.
(*b*) Urticaria on the face, chest and abdomen.
(*c*) Inspiratory dyspnœa.
(*d*) Vomiting or purging.
(*e*) Symptoms of shock with dilated pupils and sweating.

(4) The blood must not be forced too quickly into the circulation of the recipient, lest dilatation of the heart be caused. Two ounces per minute is a safe rate of injection.

Section IV.—GAS GANGRENE.

Organisms concerned.—Gas gangrene is caused by anaërobic organisms which are probably fæcal in origin. They are saprophytic. They may be divided into two main groups:—

(*a*) The Saccharolytic.
(*b*) The Proteolytic.

(*a*) This group decomposes carbohydrates with the production of acid and of carbon dioxide and hydrogen gas. It is only a feeble proteïn splitter, at any rate in the early stage.

(*b*) This group vigorously digests proteïn and produces ammonia bodies. It is only capable to a limited degree of breaking down sugars.

Infection is nearly always a mixed one. The *Bacillus Welchii* (group *a*) and the *Bacillus sporogenes* (group *b*) are the organisms most often associated.

The *Bacillus Welchii* is responsible for most cases of gangrene, but is often greatly helped by the *sporogenes*.

When the wound involves muscle, the sequence of events is as follows:—The *Bacillus Welchii*, after a latent period, produces gas and acid by its action on the sugar of the muscle. About this time the *sporogenes* begins the digestion of the proteïn. By its production of ammonia bodies it neutralises the excess of acid inimical to the further growth of the *Bacillus Welchii*. This latter bacillus at this stage begins in addition to destroy proteïn matter.

The acid produced by the *Bacillus Welchii* turns muscle red. At a later stage, sulphuretted hydrogen, set free by proteïn digestion, combining with the iron in the hæmoglobin, changes the red colour to black.

Nearly all wounds are infected by these anaërobes, which either develop and produce gas gangrene, or else die out and are replaced by pus-producing organisms. They may, however, remain latent in a wound and give rise to symptoms after the lapse of a considerable period.

Blood stream not usually invaded.—Even in cases of well-established gas gangrene the blood stream is rarely invaded until immediately before death.

Method of inoculation.—In order to develop, the organisms need to be implanted into dead tissue. This is done by the projectiles which at one and the same time carry in the organisms and devitalise the tissues. When once established in a suitable nidus within the body they are able (under favourable circumstances) to produce a further death of the tissues and thus spread away from the point of implantation.

As with other bacterial infections, the heaviness of the dose—that is the number of organisms implanted—has a decided influence on the likelihood of the bacilli establishing themselves. Foreign bodies and especially fragments of clothes are therefore much to be feared.

Tissue mostly attacked.—As seen in this war, gas gangrene is chiefly a disease of the muscles. It is met with in other tissues, and even in the brain.

Involvement of areolar tissues.—Although the disease starts in muscle as a rule, it may involve the areolar tissue later, especially if that is infiltrated with blood. It is this type which is dangerous in retro-peritoneal hæmatoma, and is responsible for a certain number of deaths after abdominal operations. (*See* Abdomen, p. 129.)

Involvment of serous cavities.—It is rarely found in the peritoneum or joint cavities, nor is it dangerous here. (*See* Joints, p. 82.)

In pleural effusions the bacilli grow more easily, and may cause extreme toxæmia if the chest is not opened by operation. If this is done the infection is not to be greatly feared. (*See* Pleura, p. 120.)

Time and onset.—It may be well established within a few hours of the receipt of the wound.

Gross morbid anatomy.—The gross morbid anatomy may be conveniently discussed under the clinical varieties of the disease:—

(*a*) Massive or segmental gangrene.
(*b*) Group gangrene.

(*a*) Here all or the greater number of the muscles of a segment of a limb, deprived of their blood supply, die and become invaded by the bacteria just as the body undergoes a universal bacterial invasion at the time of death.

(*b*) The process is limited to single muscles or to muscle groups. The infection at first remains localised to the wounded muscles, travels up and down the muscles, but finds difficulty in passing from one muscle to another. A muscle may be deprived of its blood supply, die and become invaded, or it may be attacked and succumb although its blood supply is intact.

Changes in muscle.—The spread of the gangrene can sometimes be seen. On either side of the wound there is an area, black in colour, and pultaceous or diffluent in consistence. Next is an area, dirty red in colour and firmer in consistence than the last. This area is limited toward the side of sound muscle by a yellowish white zone which stands out above the level of the muscle and is hard to the touch. This is the advancing zone. In other cases the advancing zone is absent and the changes are as follows:—

The first is the loss of contractility, the colour showing little or no departure from normal. The next change is the appearance of a dirty red tint. The next stage is that in which a greenish yellow tint is added to the red. In the last stage the muscle becomes black, diffluent and shiny on the surface.

Generation of gas in muscle.—The gas becomes clinically obvious with the onset of the red stage. It is seen as displaceable bubbles between the fibres. The muscle at this stage becomes resonant, and floats if thrown into water.

Dispersion of gas.—From the muscles the gas passes out under pressure into the areolar tissue, and then through the holes in the fascia into the subcutaneous tissue. Thus it may be found and cause crepitation at a very considerable distance from the wound, the tissue where it is found and also the underlying muscle being quite healthy and free from infection.

Part played by the gas.—The gas only exerts a deleterious influence by the pressure it produces within the fascial sheath of the limb, constricting the vessels and causing an anæmic state of the muscle favourable to an extension of bacterial infection.

Infection of tissues other than muscles.—There is often a yellowish œdema in the areolar tissue about the muscles and in the overlying subcutaneous tissue. Until late this œdema is sterile or but lightly infected, and is not of vital importance in the spread of the disease.

It is not until the death of the muscles has cut off the blood supply that the areolar tissue and skin die and become heavily infected.

Varieties of the disease.—Clinically there are three types of the disease:—

(*a*) The "Group" type, when a muscle or group of muscles are attacked.
(*b*) The "Massive" type, where a whole segment of a limb dies.
(*c*) The "Fulminating" type, an extremely rapid and fatal form and very liable to return after amputation.

(*a*) and (*b*) correspond to the two types of infection described under the morbid anatomy. The third type (*c*) is a purely clinical one, and may start as (*a*) or (*b*).

CLINICAL COURSE.

Early common symptoms of gas gangrene.—The disease is exceedingly acute in its onset. A patient left in apparent health may be found *in extremis* a few hours later. The early symptoms are pain in the limb, a rapid pulse, vomiting, and a rise of temperature. These are met with in all forms of the disease. The physical signs differ according to the type of the disease present.

"Group" type—physical signs.—In the "Group" type the limb may show no departure from the normal, or be swollen to a greater or less extent. The skin may be normal or somewhat tense and blanched if there is swelling about the wound. As a rule, even at this stage, the area about the wound is somewhat tympanitic. Crepitation is often absent. In the next stage the swelling of the limb increases, the skin takes on a dirty tint, the tympanites is more marked, and crepitation is present, and bubbles of gas escape from the wound. The skin next shows mottled purple patches, and finally becomes a greenish-yellow. It must be carefully borne in mind that the gangrene of the muscles may be far advanced though covered by an almost normal skin. At first, the muscle, if exposed by the wound, presents the usually dry surface; somewhat later it may become a dirty red, though this stage is not often seen in open wounds. Next it becomes pultaceous, and finally black with a shiny surface.

The odour of the wound depends on the type of the bacilli and the *stage of infection,* and so varies considerably. It may be little

marked, but usually, sooner or later, appears with its well known characteristics.

There is no discharge in the early stage. Soon, however, a thin, black, foul smelling fluid is exuded, changing in the later stages to an orange colour.

There is a peculiar bronzing of the skin, which has been described as associated with gas gangrene. It appears most frequently on the back or abdominal wall after wounds of this region, though not always in the immediate neighbourhood of the wound. Sometimes it disappears of itself, and at other times it is the herald of a rapid destruction of the skin that incisions are powerless to arrest. It seems to be largely a subcutaneous infection. Its actual causation is unknown.

"*Massive*" *type—physical signs.*—The "Massive" type occurs, as a rule, in a segment of a limb from which the blood supply has been cut off, usually by the interruption of the main vessel.

Two types of the disease are seen:—

(1) A limb which is already in a state of gangrene, suddenly becomes tympanitic, and the patient exhibits the common early symptoms, namely, a rapid pulse, pain, vomiting, and a rise of temperature.

(2) The gangrene, the tympanites, and the clinical signs manifest themselves at the same time.

In both varieties, in the early stages, the appearances of the skin are those seen in ordinary arterial gangrene, but infection by bacteria causes a more rapid appearance of the signs of decomposition.

"*Fulminating*" *type.*—The "Fulminating" type is exceedingly dangerous. Surgical measures, such as are sufficient to save life or limb in the first two, are often unavailing. At first it cannot be distinguished from either the "group" or "massive" type, and it is only the failure of surgical treatment to arrest the disease that reveals its nature.

It is often seen in the thigh after amputation for the disease in the leg. Here amputation through apparently normal tissue is followed, after perhaps a few hours of apparent amelioration, by a recrudescence of the disease, which extends rapidly on to the body and proves quickly fatal. It is in this type that the gangrenous process in the skin can be followed from hour to hour.

If the disease is not sufficiently acute to cause death in a short time, the skin of the whole body becomes first dirty looking and then yellow.

Late common symptoms of gas gangrene.—If cases are not progressing favourably, all the constitutional symptoms undergo an aggravation. The pulse becomes more rapid, then running; vomiting is frequent. The extremities become cold and blue, and the temperature falls. The mind often remains extraordinarily acute even to the end.

TREATMENT.

Conditions favouring gas gangrene.—The conditions which favour gas gangrene may be summarised thus:—

(1) Retention of extravasated blood.
(2) Interference with the circulation.
(3) The presence of large masses of partially devitalised muscle.
(4) Extensive fracture and comminution of long bones.
(5) Blocking back of the wound secretions by dressings which are allowed to dry and cake.
(6) Delay in mechanical cleaning of the wound.

It is evident, therefore, that all constricting apparatus should be avoided to the utmost, and that the case be evacuated at the earliest possible moment to the casualty clearing station.

It is important to remember that no muscle wound can be treated with impunity. At the same time it can be said that there is no bacterial infection which can be so easily eradicated by surgical measures.

Administration of alkali.—All patients suffering from this disease should be given alkali by the mouth, and by the vein if they are vomiting or in bad condition.

Surgical treatment.—The surgical treatment is governed by two conditions:—

(1) The state of the patient.
(2) The extent of the gangrene.

Thus, a patient who is in good condition can be submitted to an operation for the eradication of the diseased muscles, while in another patient, the same amount of disease will demand an amputation.

The surgical measures to be adopted are best considered—

(1) In "group" gangrene.
(2) In "massive" or segmental gangrene.

(1) *In "group" gangrene.*—(Patient in good condition.) The mechanical cleaning of the wound is proceeded with in the usual way, *adequate longitudinal* incisions being used. Attention is focussed on the condition of the muscles. All muscle which does not contract or bleed or is altered in colour is removed. Certain muscles may require to be followed to their attachments. By this means a limb may be saved—at the expense of a muscle or muscle group—which would have been sacrificed if crepitation and tympanites had been taken as the criterion of the extent of the disease.

(1) *In "group" gangrene.*—(Patient in bad condition.) This is most likely to occur in fractures of long bones. Here the limb will most probably have to be taken off through the fracture. If it is thought that a higher amputation is indicated on account of a crepitant or tympanitic condition of the skin, it is well to investigate the condition of the muscles through skin incisions, starting at the level of the injury, and ascertain that they really are dead nearly as far as the level of the proposed amputation.

Gas may spread subcutaneously far up the thigh, although the gangrene is really limited to the leg, and although there is no anaërobic infection of the upper part of the limb.

It is seldom right to amputate through the thigh for gas gangrene of the leg. A flush amputation through the head of the tibia or through the knee joint (preferably the former) with the removal of the heads of the gastrocnemii is usually sufficient; shock and a painful stump are prevented, and length of limb is saved.

(2) *"Massive" or segmental gangrene.*—This type is usually met with after injury to the main artery. Suture of a main artery, or if this is not possible the use of Tuffier's tubes, are to be recommended as prophylactic measures.

When the gangrene is established and the limb obviously dead, it is only a question of where to amputate. Here again the state of the muscles is the guide, and the limb should be usually removed at the lowest level of the living muscle.

In some cases where there is a grave injury, such as a shattered joint or a fracture of a long bone, it may be necessary to disregard the extent of the gangrene and amputate at a higher level as dictated by the injury.

In massive, as in group gangrene, amputation through the knee joint or head of the tibia is to be preferred to amputation through the *thigh.*

Method of amputation.—In the thigh, except in cases of grave danger, short flaps of some description should be furnished. Below the knee, where amputation will almost always be of a provisional nature, the flush method is often the best. Here it is much less painful and distressing than in the thigh.

"*Fulminating*" *type.*—(3) *The* "*Fulminating*" *type*, seen generally after an amputation through the thigh, is practically hopeless to treat.

It need only be said that re-amputation in these cases at or near the hip is very fatal, and should be rarely undertaken.

Section V.—THE ADMINISTRATION OF ANÆSTHETICS AT THE FRONT.

From the point of view of the anæsthetist, wounded men may be divided into three main classes:—

1. The lightly wounded.
2. Those suffering from serious wounds with more or less shock and hæmorrhage, the two factors being commonly associated.
3. Those suffering from a severe degree of sepsis, especially anaërobic infection.

The choice of anæsthetic depends on which of these classes the patient belongs to, as well as on the region of the body injured.

I. THE LIGHTLY WOUNDED.

These patients are good subjects for anæsthesia, so that the chief desiderata are safety, speed, and convenience. The ideal anæsthetic is one with which induction is rapid, and recovery complete a few minutes after operation, so that the patient is in fit condition for early evacuation by ambulance train.

Gas and oxygen anæsthesia meets these requirements best. With its help a greater number of cases can be dealt with satisfactorily in a limited time than with any other anæsthetic. When this method is not available, ether should be used. The ether is best administered as a warm vapour by "Shipway's apparatus," as both induction and recovery are more rapid than with the open method.

Local anæsthesia can only be employed in a small number of cases, on account of the multiplicity of wounds and their lacerated and soiled condition.

II. THE SERIOUSLY WOUNDED.

In the more serious cases the chief consideration is safety. In other words, an anæsthetic is required, which will not be harmful to a patient who is still suffering from the shock of injury, and one which will minimise the shock of operation.

SPINAL ANÆSTHESIA.

It has been urged that spinal anæsthesia would meet these requirements, especially in wounds of the legs and thighs, and would therefore be of great value in military surgery. In practice, however, it is found that the intrathecal administration of stovaine has dangers of its own when applied to men whose wounds are recent. In a large proportion of these cases the administration is followed by a great fall of blood pressure and symptoms of cerebral anæmia, that is, pallor, vomiting, loss of consciousness, and occasionally convulsions. The syncope is sometimes fatal. It is in the man who has lost blood, and whose wounds are less than forty hours old, that spinal anæsthesia is dangerous. If spinal anæsthesia is desired novocain should be preferred to stovaine.

TREATMENT OF SHOCK AND HÆMORRHAGE BEFORE OPERATION.

However urgently it may be required, operation should not be performed on a patient suffering from shock until measures have been taken to mitigate this condition. The one measure which commonly produces definite improvement is the application of external warmth.

Warmth.—Excellent results have been obtained by the application of heat from electric light lamps or by the use of an improvised hot-air bath, and, if a patient suffering from shock be put to bed and treated by these methods, or surrounded with hot bottles his surface temperature will rise, his colour improve, and, as a rule, his arterial blood pressure will go up steadily for several hours. He will then be much less likely to succumb if subjected to a severe operation.

Infusions.—Fluids are best given either by the mouth or rectum. Subcutaneous infusion produces no measureable effect in this type of case, and, if death occurs as late as 30 hours after infusion, the bulk of the fluid will still be found in the subcutaneous tissues. Intravenous injection of normal saline usually does more harm than good; the blood pressure is raised, and the pulse-rate slowed at the time of injection, but half-an-hour later the condition will be worse than ever. Hypertonic solutions produce a more lasting improvement, but with them too the ultimate result is often a lowering of blood pressure. Good results have been reported with a hypertonic *solution rendered viscous* by the addition of 4 to 6 per cent. gum

acacia. Experience with a solution of less viscosity (2 per cent. gum) has been disappointing.

Transfusion.—Blood is the one transfusion fluid which certainly produces obvious and lasting improvement in the patient whose condition has been rendered grave by hæmorrhage.

THE LIMITATION OF SHOCK DURING OPERATION.

The recently injured patient is particularly susceptible to further shock, and this susceptibility is increased by certain drugs used in the production of anæsthesia, for example, chloroform, ether, and morphine in large doses. These drugs should, therefore, be avoided in dealing with a patient who is suffering from recent wounds, and who has to undergo a severe operation, such as amputation through the thigh.

WOUNDS OF THE HEAD.

Operations on the head should be performed under local anæthesia. All tissues of the scalp are infiltrated in a circle surrounding the site of operation with a solution of novocain and adrenalin. No pain is felt even when bone and dura are dealt with. On the other hand, the forcible cutting of bone is disturbing to the patient, so that where mentality is unimpaired, omnopon or hyoscine and morphine should be given an hour before operation.

SHIPWAY'S APPARATUS.

General anæthesia may be obtained safely and conveniently with Shipway's apparatus. A warmed mixture of ether and oxygen is administered through a catheter passed down the more patent of the two nostrils. If a really warm vapour is to be obtained with the Shipway apparatus, the delivery tube from the Thermos flask to the mask must not be more than 30 inches in length, and it should be covered with some non-conducting material such as Turkey towelling or Gamgee tissue. When the theatre temperature is below 70° F. the Thermos flask should be filled with water at about 200° F. Another point to be borne in mind when administering ether vapour is that irritating substances are formed if air or oxygen be bubbled through ether for more than two hours. The ether bottle of a Shipway apparatus should therefore be emptied from time to time, and a completely fresh supply substituted; the waste ether may be kept *in a stock bottle* and used for cleaning the skin before operation.

WOUNDS OF THE CHEST.

Ether should not be administered to a patient with a perforating wound of the chest, as it may provoke fresh intrathoracic hæmorrhage. For small operations, such as the resection of a rib, local anæsthesia may be employed. The intercostal nerves of the rib to be resected and of the rib above are blocked by injection of a solution of novocain and adrenalin into the subcostal grooves close to the angles of the ribs. For more extensive operations, requiring general anæsthesia, a preliminary injection of morphine gr. 1/6, hyoscine gr. 1/100, and atropine gr. 1/100 may be given, followed by gas and oxygen, or by a minimal amount of warm chloroform vapour with oxygen.

WOUNDS OF THE ABDOMEN.

For patients with wounds of the abdomen, gas and oxygen, or a warmed mixture of ether vapour and oxygen, are the best. Compared with "open ether," warm vapour gives a more rapid and quiet induction, easier breathing, and diminished heat loss during operation and less vomiting afterwards.

Men wounded in the abdomen are especially liable to develop bronchitis, perhaps owing to deficient movement of the lower part of the chest. In a series of these cases anæsthetised with open ether, 54 per cent. developed bronchitis after operation. In a comparable series anæsthetised with warm ether vapour, the percentage of bronchitis was only 14.7.

BLOOD PRESSURE DURING OPERATIONS ON THE WOUNDED ABDOMEN.

During the course of an ether vapour anæsthetic the blood pressure shows a tendency to rise, but if there is much manipulation of gut and mesentery, it will gradually fall. Exposure of gut outside the abdominal cavity produces very serious effects. If more than 2 or 3 feet are exposed, the blood pressure will commence to fall after a few minutes, and will continue to fall rapidly until the gut is replaced. This effect is seen when stomach and omentum are exposed, and even with the omentum alone. The indication is that surgeons should make sufficiently large incisions, and work as far as possible with the *gut lying inside* the abdomen. Covering the exposed gut with pads *wrung out in hot saline* does not prevent the fall of blood pressure.

Exposure of intestine.—Exposure of gut produces far less effect if the patient is not under an anæsthetic. Men arrive from the line with several feet of intestine prolapsed through a wound, yet their blood pressure may be within normal limits. In one case more than two-thirds of the small gut had been ouside the abdominal cavity for at least four hours, and this man's blood pressure was 142 mm. of mercury, and his pu'se rate only 108. The patient recovered.

Do not turn the patient over.—Rapid fall of blood pressure in abdominal operations may also be caused by turning the patient on his side. This effect is only seen if the patient has been under the anæsthetic for a considerable time before being turned. At the end of an abdominal operation the patient may be in good condition. He is then turned on the right or left side so that the surgeon may excise a wound in the back. In a few minutes there is a great fall of blood pressure, and the radial pulse disappears. It may be hours before the patient recovers this lost ground. If possible, *wounds of the back should be dealt with before laparotomy*, as turning the patient has no ill effect during the first half-hour of an ether anæsthesia.

Chloroform.—If chloroform be used in abdominal operations, the blood pressure will fall during administration and for some hours afterwards. This drug should therefore only be used during the period of induction, and then only in very small quantities.

Ether.—Ether is contraindicated in those patients whose condition is very grave before operation, and when projectiles have penetrated the chest as well as the abdomen. With these two classes of case the best results have been obtained with gas and oxygen.

Gas and oxygen.—The anæsthetist's part is to keep the patient unconscious and quiet; he should not try to produce abdominal relaxation. Sufficient oxygen should be given to abolish the least trace of cyanosis, and rebreathing should be avoided, as it causes laboured respiration, which is troublesome to the surgeon, and is followed by a collapse which is dangerous to the patient. It is part of the surgeon's work to produce and maintain relaxation of the abdominal muscles by local anæsthesia. The line of the incision is infiltrated with a 1 per cent solution of novocain with adrenalin. Each layer is infiltrated immediately before being cut. This procedure does not add five minutes to the time of operation. The anæsthesia will last for about fifty minutes; if the abdomen cannot be closed within this period, parietal peritoneum and muscles on each side of the incision must be infiltrated from within

outwards with a solution of quinine and urea hydrochloride. The relaxation produced by local infiltration is more complete than can ever be obtained by ether or chloroform anæsthesia. In order to maintain it, the surgeon must work gently, *i. e.*, use a sharp knife and avoid forcible dragging and tearing.

Patients anæsthetised in this manner will regain consciousness a few minutes after operation, and are able to take fluids by mouth at once. A striking feature of the post-anæsthetic phase is the absence of restlessness and discomfort, so that these patients seldom require morphia.

III. PATIENTS WITH SEPSIS.

The patient whose condition is rendered grave by sepsis will stand an amputation far better than the man who is suffering from shock. In the septic case, gas and oxygen again gives excellent results, but spinal anæsthesia, warm ether vapour, and intravenous ether, are also comparatively safe. Chloroform, however, is to be avoided, as it is often followed by a slow fall of blood pressure, which ends in death during the twelve hours succeeding operation.

Section VI.—SECONDARY HÆMORRHAGE AND WOUNDS OF LARGE VESSELS.

RECURRENT AND SECONDARY HÆMORRHAGE.

The rules laid down for the treatment of primary hæmorrhage are equally applicable to the recurrent variety.

Secondary hæmorrhage.—The gradual improvement in technique of treatment of wounds at the front during the present war has materially lessened the number of cases of secondary hæmorrhage in stationary and base hospitals. Nevertheless this complication still remains one of the most serious and difficult problems that have to be met. Secondary hæmorrhage is not frequent during the first week, except perhaps in face and jaw cases. During the second week it becomes more frequent, while during the third week it reaches its maximum frequency, especially in wounds of the extremities. For this reason every effort ought to be made to get wounds into such a condition of sterility that secondary suture can be performed.

Ligature of bleeding vessel.—When profuse hæmorrhage occurs a tourniquet should be applied, if possible, and the bleeding point sought for in the wound and treated by ligature of both ends of the bleeding vessel. Ligature of the main artery in continuity is not to be recommended, as there is abundant evidence in the history of earlier military surgery and during the present war to prove that disaster is likely to follow either from gangrene of the part supplied or from recurrence of the hæmorrhage. A possible exception is in the case of hæmorrhage from the gluteal artery, when the internal iliac or its posterior division may be ligatured. If a tourniquet can not be applied, as in the case of bleeding from wounds of the head or neck, or from a vessel in the axilla, it is justifiable to place a temporary ligature or clamp on the main artery while the bleeding point or points are being sought for and secured. The clamp or ligature should be so applied that no damage is inflicted on the inner coat of the artery.

Plugging.—If the condition of the tissues is such that a ligature can not be applied with any hope that it will be permanently efficient, it may be necessary to resort to the objectionable method of plugging, and in this case the plug must be retained for a period of at least 48 hours if the bleeding has been severe.

Forci-pressure.—If the position of the bleeding point renders it impossible to apply a ligature, the difficulty may be surmounted by the application of pressure forceps left in position.

If ligature in continuity is decided upon for any reason, the most distal point of the vessel that will control the hæmorrhage should be selected for its application. When a main artery in a stump gives way it is good practice to apply a ligature through a fresh incision in close proximity to the site of amputation.

When other means have been exhausted and the general condition of the patient warrants the risk, a recurrence of secondary hæmorrhage in the extremities should be treated when practicable by removal of the limb.

Blood transfusion.—Of late some brilliant results in the treatment of the anæmia due to severe secondary hemorrhage have been obtained by blood transfusion. (*See* p. 29.)

WOUNDS OF THE GREAT VESSELS AND ANEURISMS.

In some cases wounds of the great vessels are not accompanied by severe primary hæmorrhage; in others a preliminary sharp spurt is followed by spontaneous cessation of bleeding. In many instances the main vessel or vessels of the limbs have been completely severed without the occurrence of any material hæmorrhage, either externall / or into the tissues.

Suture of vessels.—Suture of injured blood-vessels, either end to end or lateral, has been employed during the war in a few cases only. The procedure may be carried out at the front before sepsis has occurred with greater prospects of success than at the base. At the base, while the patients are awaiting evacuation to England, it is rarely necessary or desirable. The vessels in this case are comparatively fixed and difficult to free without damage to the coats, as well as rigid in themselves; hence, if sutures are introduced the tension upon them is far greater than in the case of normal arteries. *Cases, however, do occur* in which suture can be carried out. This *operation is accomplished* with a very fine needle and silk impreg-

nated with liquid paraffin, and requires very delicate manipulation and good technique. In the hospitals on the lines of communication suture has been carried out chiefly for arterial hæmatomata and arterio-venous aneurisms.

Tuffier's tubes.—In such vessels as, for example, the common carotid, the femoral, and the popliteal, where ligature often leads to acute local anæmia and gangrene, Tuffier's tubes may be tried to maintain the main current pending the increase in the collateral circulation. The results attending this method of treatment in a few cases are definitely in favour of a more extended trial.

Ligature of vein as well as of artery.—In most cases of arterial injury in which interference is necessary the operation will consist of ligature of the vessel above and below the injured part. Simultaneous ligature of the vein as well as of the artery does not increase the risk of gangrene. On the contrary, there is good evidence that this risk is actually lessened by tying the main vein.

Arterial hæmatoma.—At first a diffuse pulsating swelling appears. The blood-containing cavity as a rule becomes localised, and a so-called false aneurism is developed. This not infrequently becomes consolidated without surgical treatment. Localised false aneurisms rarely need early treatment.

Early operation is called for under the following circumstances:

(*a*) Secondary hæmorrhage.
(*b*) Continuous increase in size.
(*c*) Secondary diffusion.
(*d*) When the tumour is large, becomes solid throughout and gives rise to danger of gangrene from pressure on the collateral vessels.
(*e*) When suppuration threatens.

For an arterial hæmatoma, should suture or the use of Tuffier's tubes be impracticable or unnecessary, a ligature should be placed on each side of the wound in the vessel, care being taken to close also any branch which may arise opposite the point of injury. When early operation is required a tourniquet is always to be employed, if practicable.

If the vessel be the external iliac, the abdominal aorta may be controlled by a long piece of strong drainage tube drawn tightly round the body.

Operations on aneurisms.—In other parts, if a tourniquet be inapplicable, hæmorrhage may be controlled by direct pressure on the

wound in the vessel by a finger introduced into the cavity of the hæmatoma. Temporary ligature or clamping of the vessel proximal and distal to the injury and well away from it has proved of service in some cases. The greatest care should be taken in this case to avoid injury to the vessel, and the temporary ligature or clamp must not be left on too long. The most hazardous operations are those at the root of the neck.

Arterio-venous aneurisms.—In the absence of any of the complications mentioned above the cases should be treated expectantly and transferred to England. If operation is imperative the vessels should be ligatured above and below the communication unless the case is a suitable one for suture and the necessary skill and appliances are available. Tuffier's tubes may be found useful in certain cases where ligature of the main artery is likely to be attended with untoward results.

Proximal ligature of the artery alone is not to be recommended. Temporary broad ligatures or light clamps at a distance from the aneurism to control the bleeding during a conservative operation may be found useful in cases when a tourniquet cannot be applied.

Aneurismal varices should be treated by the expectant method and may often be disregarded entirely.

Section VII.—TREATMENT OF WOUNDS AT THE BASE.

As pointed out by Carrel, every infected wound passes through three stages. 1. The pre-inflammatory stage, lasting from 12 to 48 hours. 2. The inflammatory stage, which lasts from several days to several weeks. 3. The stage of suppuration.

It is during the first stage that the most radical measures can be carried out with impunity. Every effort must therefore be made to deal with wounds requiring operation during this stage.

In the second stage extensive operations cannot be carried out without risk of producing septicæmia, or, at least, grave exacerbation of the local and depression of the general condition of the patient. During this period, therefore, the greatest judgment must be used in deciding as to the nature and extent of an operation. In the case of gas gangrene, of course, wide excision of affected muscle and extensive opening up of the wound or amputation must be done to save life.

In the period of suppuration, experience has shown that interference is frequently attended with risk, but the risk is not so great as during the second period. Tetanus and gas infection have frequently been lighted up by operation long after the infliction of the wound. Nature's barrier, which has been established round the wound in its passage through the previous stage, must be disturbed as little as possible, and with due approciation of the risk run. Anti-tetanic serum should be administered before operation.

Rest after journey.—When a badly wounded patient arrives at the base, it will probably be found that his local and general condition have been more or less seriously affected by the journey from the clearing station. Consequently, if the question of an operation should arise, the surgeon must exercise sound judgment in deciding whether or not to operate immediately. Unless unequivocal indications arise (such as the onset of gas gangrene) he may be wise to temporise, in the hope that the temperature and pulse will settle down when the patient has had rest.

Delayed primary suture.—The progress of a wound while at the base will depend largely upon the length of time that has originally elapsed before arrival at a casualty clearing station, and also upon the completeness of the first operation at the front. The experience of surgeons at the base has been that, if the technique has been good and the case has been seen early enough, *many wounds may be closed at once by suture.* Little active interference is required beyond careful attention and the avoidance of contamination during subsequent dressings. The most scrupulous aseptic technique is of far more importance than any individual method of treatment which may be the fashion at the moment.

Infected wounds.—Deep, open wounds, when patients reach the base, are often grossly infected. Bacteria are plentiful in the cavity of the wound, and the walls are also infected to a considerable depth.

The bacteria which influence the course of wound infections divide themselves into three groups:—

1. Anaërobic spore-bearing bacilli, *e. g.*, *B. perfringens*, *B. sporogenes*, *B. tetani.*
2. Pyogenic cocci, *e. g.*, streptococci and staphylococci.
3. Bacilli of the type of *B. coli*, *B. proteus*, and *B. pyocyaneus.*

Varieties of bacteria.—Apart from tetanus, infection from anaërobic spore-bearing bacilli is chiefly of importance, in that it gives rise to gas gangrene in the early days of the wound. After the first few days it is of less importance, except in so far as organisms like *B. sporogenes* break down the albumin of the discharges into simpler bodies, which furnish suitable pabula for the growth of other organisms.

Streptococci are present in all stages of wound infection, and are responsible for most of the serious complications (septicæmia, cellulitis, and pocketing of wounds). Staphylococci are especially prominent in the later stages of wound infection, and are relatively of little importance.

Infections with *B. proteus* are common in all stages of wounds. *B. pyocyaneus* is seen in the later stages. The latter seems to be very often a hospital infection, and is evidenced by the green colour of the dressings. As compared with streptococcal infections, this is of little moment.

Antiseptics.—In a recently inflicted wound, it may be possible, by a thorough surgical cleansing, to reach most, if not all, of the *infecting organisms,* and the application of antiseptics may perhaps

help considerably in restraining the infection. The problem is, however, an entirely different one when a patient with a large wound reaches the base with established sepsis of several days' standing, for the walls of the wound then contain innumerable organisms, which no antiseptic in a concentration that can be used clinically is capable of killing, even if it could penetrate into the numerous recesses of the wound cavity.

The treatment of wounds will necessarily vary. In many of those which are superficial, and which have been excised, but not sutured, at the front, a "delayed primary" suture may be performed within one, two, or three days of arrival at a general hospital. In other slight cases, healing is rapid under simple dressings, and no suture is required.

Sterilisation of wounds.—In all extensive and deep lacerated wounds, and especially when these are complicated by fracture of the large bones, the main object of treatment should be to sterilise the damaged tissues, so that the wounds may be closed by suture as soon as possible. There is no doubt that by far the most efficient method which has yet been practised is that of Carrel, and, whenever this method is possible, it should be employed. The progress of sterilisation must be followed by the aid of a bacteriologist, and suture should not, as a rule, be attempted until the wound is approximately sterile. The principles and details of this method are fully described in the recent work on "The Treatment of Infected Wounds," by Carrel and Dehelly, and other methods of wound irrigation are now but little practised.

Secondary suture.—When the wound is sufficiently sterilised, its edges are drawn together, either by strapping or by deep sutures, without any refreshing of the edges or removal of granulating surfaces.

Another common method of preparing wounds for suture is the application of the bismuth sub-nitrate, iodoform, and paraffin paste (the B.I.P.P. of Professor Morison), which is rubbed into the raw surfaces, as already described on p. 14. In old wounds with granulating surfaces the tissues are simply drawn together after the application of the paste.

Need for splinting.—The later treatment of chronic suppurating wounds must be carried out on the same general principles as in similar conditions in civil practice, but, whatever applications may be employed, it is essential that a wounded limb shall be immo-

bilised on a splint, which is so applied that the dressings can be changed without movement of the affected part.

In addition to the various local applications that may be employed, immersion in antiseptic baths or exposure to the air and sun have been tried. The latter is sometimes useful for wounds that are atonic and very sluggish, but care must be taken to protect the wound from undue desiccation by the employment of a thin gauze veil moistened by an antiseptic fluid.

Section VIII.—AMPUTATION.

PRIMARY AMPUTATIONS.

Shock and amputation.—Many men who would certainly die if subjected to immediate operation, will survive if they are allowed sufficient time to get completely over the shock of the injury and its attendant conditions, and the more experienced the surgeon the less is he likely to hurry on a severe primary amputation. (*See* "Shock," p. 21.)

It is, of course, evident that delay in removing a badly smashed limb may result in dangerous sepsis, and there is no doubt that the threat of gas gangrene may necessitate operation earlier than might be wished. Much must therefore of necessity be left to the discretion of the surgeon in each case, and, as it is only after a considerable experience at the front that really sound opinions can be formed, it is very necessary that *those who have not had this experience should seek the advice of those who have* before a decision is come to in a doubtful case.

Flaps to be made.—When the condition of the limb and of the patient permit, a primary amputation should be performed by one of the recognised methods practised in the usual circumstances of civilian surgery, suitable flaps being provided and sutured. If the amputation has been performed under good aseptic conditions and through sound tissues, the wound may be sutured at once, or in times of stress may be carefully dressed with the intention of closing the flaps by "delayed primary suture" in the course of the next 48 hours. If these conditions are not obtainable, the flaps may be partially sutured and the stump drained.

The seat of amputation has been much discussed, but the best rule is that as much of the limb as possible should be saved, quite regardless of the typical "seat of election" as prescribed in former years; amputations through joints are, however, to be avoided as a rule.

Departure from these ideals may be necessary, either because of the condition of the patient himself or of his limb.

Method of removal of smashed limbs.—If the patient is desperately ill from the combined effects of loss of blood and other complications, his condition may be such that the additional shock of a high amputation may be quickly and inevitably fatal. In a pulseless patient who has a smashed and still oozing limb the best thing is to remove it as quickly as possible by cutting through the soft tissues at the site of fracture, subsequently clipping away torn and ragged tissues and tying the main vessels.

Not more than ten minutes need be spent on such an operation, and, if it is conducted under the influence of gas and oxygen anæsthesia, many apparently hopeless cases can be saved, for there is very much less shock than would be entailed by either a longer operation or by the cutting through healthy and sensitive skin and muscle higher up the limb. In such a case the making of a suitable stump must be left to a future time, but should be done as soon as safety permits.

Smashed limbs with multiple wounds.—In another class of case the leg or the forearm may be smashed beyond recovery, while the thigh or the upper arm is the seat of other severe wounds complicated by the presence of mud, or portions of shell, or of clothing. It is quite unwise in such a case to amputate high up the limb, and it is best to perform an amputation close above the fracture, and leave the flaps open or stitched back. If this is not done, not only is the patient exposed to more severe shock by a high amputation, but his stump may slough and a yet higher-up removal may be necessary if he ultimately does survive.

SECONDARY AMPUTATIONS.

The general principle of removing as little of the limb as possible holds good in "secondary" as well as in "primary" amputations.

In the upper extremity.—Any part of a hand should be saved; in the forearm it is most advisable to save the insertion of the pronator radii teres so as to permit of rotation of the forearm stump; at the elbow, the condyles should always be removed, as they make an impossible stump for the instrument maker; in the arm it is always advisable to amputate below the shoulder-joint, both because of the lesser immediate risk, and also because, after disarticulation of a septic arm, sepsis is very liable to spread into the scapular region.

In the lower extremity.—Amputation through the metatarsus gives a useful foot; Chopart's operation, on the other hand, is bad, and results in an insecure and "rocking" stump; Syme's amputation is good, and is better than Pirogoff's; the longer the leg stump the more opportunity is provided for an artificial limb; knee amputations are not good in the presence of sepsis; the longer the thigh stump the better is the walking power; hip-joint disarticulations are extremely fatal, and should be avoided whenever possible.

Guillotine amputations rarely necessary.—The method of amputation should be such as to provide skin covering for the stump, and this may be done by either the "circular" or the "flap" method. "Flush" or "guillotine" amputation is very rarely necessary. As already mentioned in the section on gas gangrene, it may be required in the leg in cases of gas-infection complicating fractures of the tibia and fibula, but it should not be practised in the thigh or upper extremity.

Methods of amputation.—If the part through which the amputation has to be done is very septic, free drainage is best secured by turning back the flaps and fixing them in this position by sutures for a few days.

At a later stage it is very necessary *to draw down the skin of the stump* by a suitable extension apparatus. If this is not done in a suppurating stump even long flaps may retract so as to leave the stump bare and raw, while, on the other hand, careful traction will ensure the covering up of a stump even if the flaps are scanty.

In many cases flaps which cannot be safely sutured at the time of the operation can be closed by secondary suture after sepsis has subsided.

Gas gangrene is a frequent cause of amputation, especially in men who have lain out for a long time before being brought to the casualty clearing station. (*See* Section IV for methods of operating on such cases.)

Section IX.—FRACTURES.

THE TREATMENT OF FRACTURES AT THE FRONT.

All fractures caused by gunshot wounds are liable to be complicated by severe laceration of the soft tissues, especially where the injury is caused by ragged fragments of shell which may tear away large masses of muscle and skin and bruise the tissues to a great depth from the exposed surface. Bullets also may cause such extensive tearing that the part looks as if it had been struck by a shell fragment. This is frequently the case when the fracture is due to a bullet fired at a very close range, and when the bone struck is a large one, such as the femur or the humerus. In such cases it is the exit wound which is so large and lacerated, and this is due to the fact that the bullet, travelling at the height of its velocity, not only smashes the bone, but also imparts its momentum to the shattered fragments and drives them in front of it; the resulting wound is caused as much by the broken fragments as by the bullet, and the wound is often said to be of the "explosive type." In other cases where the entrance and exit wounds of a bullet are small, there may yet be much tearing of the muscles, and as a result the limb is liable to become greatly swollen by the subsequent interstitial bleeding.

At the regimental aid post.—The treatment of any fracture should commence as soon as the wounded man is seen by the surgeon, and the first essential is to steady the limb and temporarily fix the broken bones so that no further movement of them is permitted. In the case of the upper extremity, bandaging the arm to the side may be sufficient, but in the case of the lower extremity, some sort of emergency splint is required. If nothing can be obtained then the legs may be bandaged together till the regimental aid post is reached.

Here, or at the field ambulance, the limb should be most carefully splinted, so that no unnecessary pain or injury may be caused by the transport to the casualty clearing station. It is most important to remove the improvised splints and dressings first applied as soon as possible, and never in any circumstances to bandage the limb without first putting on a splint and a large quantity of cotton wool. Much

harm is often done by bandages applied tightly over first field dressings by the comrades of the patient, and care should be taken at field ambulances and clearing stations to see that bandages have not become too tight owing to the swelling of the limb.

A triangular bandage is often better than the roller applied spirally.

At the casualty clearing station.—As soon as the condition of the patient permits, he should be taken into the operating theatre, and the fracture examined and treated under an anæsthetic. In most cases examination by X-rays should precede operation.

Fractures caused by bullets (or more rarely by a very small shell fragment), and in which the entrance and exit wounds are quite small and the limb is not swollen by bleeding, are the only cases in which it is right not to open up the wound. They form a very small minority.

Method of operating.—The routine treatment should consist in the complete exposure of the fracture by longitudinal incisions, in the excision of all damaged and soiled tissues, and the exposure and cleaning of the injured bone.

The greatest care should be exercised in getting rid of all kinds of foreign bodies and in the removal of quite detached and loose pieces of bone. As a rule, pieces of bone should not be removed if they are not completely loose, and this is especially true of large fragments. But in some cases the bone is so crushed and contaminated with mud that it is wise to excise attached fragments also, and, if this is done, care should always be taken to leave the periosteum if possible. It has been found by experience that, even when large pieces of a shaft have been completely shot away, the loss of bone does not necessarily prevent good union and the restoration of a useful limb. Mere loss of bone, therefore, very seldom calls for amputation. After the loose fragments have been removed and the damaged soft tissues excised, the exposed surfaces of the injured bones may often be carefully curetted with advantage, and this is especially true if an oblique fracture has left a large surface exposed. It is very desirable that the thorough treatment of fractures should be undertaken at the casualty clearing stations before the patient goes to the base hospital, for if a day or more has elapsed since the injury it is exceedingly difficult to obtain a satisfactory result.

Primary suture.—After the excision and treatment of the wound is completed, the skin should not be sutured except when the injury *is not extensive and the* patient can be retained for a week or more. *Drainage tubes are not* usually necessary if the wound has been

widely opened up, but, if they are required, they should not lie across a limb so as to be between the fractured ends of the bone. If gauze is placed in the wound, it must never be tightly packed or so placed that it becomes entangled in the fractured bone and is made difficult to remove.

The particular splints required for each separate fracture should be applied before the patient comes round from his anæsthetic. In some cases the splint applied at the time of operation is suitable for the subsequent treatment also, but in many others the splint which is the best during transport by ambulance car and rail is not the best for the later stages of treatment, and must be changed.

Delayed primary suture is to be done whenever possible, and should usually be performed on the second or third day after the operation.

If suture cannot be done, and if the wound is extensive and the bone is badly shattered, one of the best methods of treatment is the Carrel-Dakin, whether the patient is retained in the casualty clearing station or whether he is evacuated by train. Many of the worst cases of fracture of the femur have been treated very satisfactorily in this way during the past year.

TREATMENT OF SOME SPECIAL FRACTURES.

A. *Of the humerus.*—At the first aid post and field ambulance these fractures are best treated by bandaging the arm to the side with the elbow flexed beyond the right angle, a layer of wool being placed between the limb and the body. A piece of Gooch's splinting may be added reaching from the acromion to the elbow on the outer aspect of the arm. The internal angular splint and modifications of it should not be used except for fractures of the lower extremity of the bone.

At the casualty clearing station it is important that the surgeon on duty in the dressing room should make a *special note of the condition of the main nerves*, as the patient may have been anæsthetised before the operating surgeon has an opportunity of making observations.

Splints for humerus.—The best splint for general use is the straight Thomas arm splint maintaining extension in the abducted position. The modification with the swivel ring should be chosen so as to enable the arm to be brought to the side when necessary during transport. It should be arranged at the base that this splint should be restored to the abducted position as soon as the patient is in bed.

Other splints in common use are:

(*a*) Clarke's wooden humerus splint. An internal angular splint with a hinged back piece along the upper arm. This is a good splint when there is no extensive wound.

(*b*) Jones' extension humerus splint.

(*c*) Depage's modification of Le Clerc's splint.

Each of these two latter splints is fitted with a crutch for the axilla so that extension may be employed. They are particularly suitable for patients who can walk (*see* also p. 67).

B. *Of the forearm.*—At the aid post or field ambulance the internal angular splint with a short back forearm splint should be used.

At the clearing station all these fractures should be put up in full supination.

C. *Of the femur.*—If no splints are available the legs should be tied together. On the field of battle the improvised splints should, if possible, fix the hip and knee joints.

These splints should be put on as soon as possible. They are applied over the clothes and boot and the latter should not be removed. The laces should be cut.

Only two splints need be considered:

(1) Thomas knee splint.

(2) The long Liston (broad pattern.)

Application of the long Liston.—The long Liston splint is only to be used when a wound of the buttock prevents the use of the Thomas.

It should be applied with triangular bandages as they cause less pain than the roller bandage.

A perineal band has been found to produce œdema of the thigh and should not be used.

APPLICATION OF THE THOMAS SPLINT.

(1) The limb is steadied by extension produced by traction on the foot, which is kept up by an orderly until the extension is produced by the splint.

The improvised splints are cut off.

(2) The limb is slightly raised.

(3) A clove hitch is made of 9 feet of strong bandage so arranged that one tail is 18 inches longer than the other.

(4) The clove hitch is placed round the ankle and loosely adjusted *so that the knot lies below* one malleolus.

(5) The long tail is then led across the sole of the boot just above the level of the heel and passed through the bight of the clove hitch on the opposite side of the ankle. It is then brought down again. There will thus be traction on both sides of the foot.

If the boot has been removed the ankle must be adequately protected by plenty of cotton wool.

(6) The ring of the Thomas splint is now passed over the foot and adjusted against the tuber ischii, traction on the foot being still maintained.

(7) Extension is now produced by pulling on the two tails of the clove hitch and the splint pushed home. Each tail is now taken separately and passed outside the lateral bar and round the notch on the end of the splint. They pass in opposite directions round this notch, and are secured by being tied in a bow.

Extension has thus been produced. The limb has now to be suspended in the splint.

(8) Slings of bandage are passed behind the knee and leg and fastened to the side bars. These bars should be midway between the anterior and posterior aspects of the limb.

(9) To prevent the limb from rising from its bed, two pieces of bandage or narrow fold triangular bandages are placed in front of the leg (one below the knee and one above the ankle). They pass behind the side bars and are tied in front over the external bar.

The limb is now extended and rests securely in its cradle. This permits the wound to be dressed with a minimum of pain.

(10) If the wound is on the anterior surface of the thigh a piece of Gooch's splinting, of sufficient length, is placed on the back of the thigh and held in place by bandage or adhesive plaster slings. The wound in front, exposed by cutting away the clothing, is dressed. Another piece of Gooch's splinting is laid on the front of the limb and secured by roller bandages, narrow fold triangular bandages, or adhesive strapping.

(11) If the wound is on the posterior surface of the thigh the limb is raised, the clothing cut away, the dressing applied, a piece of Gooch's splint laid under it, and the whole retained in place by slings. Gooch's splinting is now applied in front, and retained in place as above.

A ham splint may be used to replace the posterior Gooch's splinting.

(12) A roller bandage or pad of wool is placed beneath the ring at its junction with the external lateral bar. Or the internal lateral bar is fastened to the limb by a loop of bandage. This is done to keep the ring on the tuber ischii.

(13) "Sinclair's prop" may be adjusted to the under side of the splint in case the traverse of the stretcher has to be broken in getting round corners.

(14) The extension is again tightened if it has become loose, and is made more perfect by roping the extension tails, as they lie within the lateral bar, by means of a small piece of Gooch's splint, after the manner of the Spanish windlass.

(15) The foot is steadied by a figure-of-eight bandage applied over the splint or by "Sinclair's prop."

(16) The stretcher suspension bar is adjusted, and the two side bars of the splint suspended separately to the top of the suspension bar in the abducted position. They should also be stayed laterally, but not too tightly. The bandages used should be strong, as the slings that support the leg are apt to break with the jolting of the ambulance.

(17) The extension should be tightened by twisting the windlass if it becomes loose in process of evacuation to C. C. S.

At the Casualty Clearing Station.—The patient should be anæsthetised before the splint is removed.

The wound and fracture are treated in the standard way. (*See* p. 58.)

The extension is now applied with strapping or glue.

A Thomas splint is again adjusted, care being taken that the skin over the tuber ischii is dry and clean (it can be treated advantageously with picric acid).

The leather ring of the splint should have been rendered supple by the application of soft soap.

The Thomas splint may be somewhat bent at the knee if thought advisable, but this bending must not be excessive on account of convenience in transit. The natural anterior bow of the femur should be carefully retained.

The splint should then be slung on the stretcher suspension bar. If the patient is to remain some time at the C. C. S., the foot should be supported by a foot-piece.

If a Thomas's splint can not be used, a bracketed long Liston is to be used, or possibly a Robert Jones abduction frame.

The patient should travel to the base on the stretcher on which he leaves the C. C. S.

FRACTURES BELOW THE KNEE.

Improvised splints.—Improvised splints should fix the knee and ankle.

Provisional splints.—A Thomas splint should be used for fractures immediately below the knee joint.

For others a Barbour back splint, with footpiece and sidepieces, is the best.

Attention must be paid to firmly fixing the top of the splint to the thigh. If this is not done the splint is practically useless, and acts as a lever to move the fracture.

At C. C. S.—At the casualty clearing station the standard cleaning operation is performed, and Thomas's or Barbour's splint is applied.

TREATMENT OF FRACTURES AT THE BASE.

On admission let the man rest.—The transport of patients from the casualty clearing station to the base induces a certain degree of shock in many cases of fracture, and a more accurate estimate of the ability of the patient to resist infection can be formed after one or two days' complete rest than is possible while increased septic absorption, due to the mechanical jolting of the journey, is still in evidence. Interference, either operative or mechanical, involving administration of a general anæsthetic, is, therefore, inadvisable at this stage, unless imperatively demanded by the threat of impending disaster; and, since fractures habitually arrive at the base suitably fixed and adequately drained, such disaster is practically limited to the development of "gas gangrene," which is now comparatively infrequent at the base.

Since the primary fixation has probably been applied under anæsthesia without the check of the patient's own sensations, its immediate adjustment, with particular reference to known pressure points, may prevent the formation of skin sores which, if once established, handicap considerably the mechanical treatment of the fracture.

Suture if possible.—If at the end of about 48 hours the condition of the patient and of his wound are satisfactory *the latter should be closed by suture in most cases*, as it is of the greatest importance to get the compound fracture converted into a simple one as soon as possible.

Every fracture left with an open wound presents three problems of paramount importance:

(1) Control of sepsis.
(2) Correction of deformity.
(3) Maintenance of mobility of joints.

Whilst the preservation of life and limb depends on the control of sepsis, such control is more easily maintained when the deformity is corrected. This correction should, therefore, be commenced as soon as possible without waiting for subsidence of the sepsis. The maintenance of the mobility of joints will be discussed under the heading of Massage.

The following description illustrates the methods commonly employed at base hospitals.

ROUTINE INVESTIGATION.

X-rays.—On admission, X-ray examination is undertaken to ascertain the presence or absence of a foreign body and the degree of deformity, and then, after sufficient time has elapsed to allow of recovery from the effects of the journey, the fracture is put up in the best position ascertainable by the eye. Extension is applied until reduction of the deformity is judged to have taken place, and a second radiogram is taken with the patient in bed. If the position is satisfactory and can be maintained, the next radiogram is taken when the fracture is beginning to consolidate. Any necessary correction can then be made, and is followed up by radiography until proper alignment is established. Stereoscopic antero-posterior and single lateral plates are of great assistance.

Tape.—Measurements of length are taken at the end of each week. The most careful measurements must be regarded as liable to an error of ½ inch.

Blood culture.—The blood is examined for streptococcal infection under the following circumstances:

If the temperature rises continuously for four days or maintains an oscillation of three or more degrees for ten days without a pocket to account for it; if secondary hæmorrhage, *however slight*, takes place; if a pyæmic joint infection or a pyæmic abscess develops.

Aspiration of a neighbouring joint.—Any fracture near a joint is frequently accompanied by an effusion into that joint. If this *effusion contains* blood, there is probably a fissure running from the *fracture to the joint*, and suppurative arthritis, due to direct exten-

sion of pus from the fracture, is liable to occur. If the effusion is only synovial, this complication need not be feared.

PATHOLOGY.

The infected gunshot fracture differs from the infective osteomyelitis of civil practice in that in the one case the missile carries infection and opens the bone at the same time; while in the other case, where there is no open wound, microbes go on growing in the bone until it is opened by the surgeon. The path of least resistance for the microbes in a fracture is out into the wound, and not into the bone; consequently, "spreading" suppurative osteomyelitis does not often occur, and the pus which comes out of the bone is derived from the surface of the fragments and the walls of fissures. A limited chronic osteomyelitis leading to the formation of sequestra is, however, frequently set up by the growth of microbes for an inch or so into the bone ends, and this may account for the condition of those patients who become progressively emaciated and more "septic," although the wound looks healthy and the blood remains sterile. The growth of organisms in bone, as in other tissues, is greatly accelerated by interference with its blood supply, and for this reason incisions designed to improve drainage should respect, so far as possible, the vessels known to supply the fractured bone.

TREATMENT OF SEPSIS.

Local operation.—All readily accessible foreign bodies are removed, including bone fragments devoid of periosteal attachment.

Pockets are opened by longitudinal incision throughout their whole length, the operation being performed in bed with the least possible disturbance to the position of the limb.

Enlargement of a wound after the first 48 hours is done by simple incision, as extensive excision operations at this stage may be dangerous.

Indications for amputation.—Amputation may be required for—

Gangrene.
Extension of infection to neighbouring joint.
Septicæmia.
Secondary hæmorrhage in a patient with septicæmia.
Recurrence of severe secondary hæmorrhage.
Progressive emaciation with delayed union.

MECHANICAL TREATMENT.

METHODS OF APPLICATION OF EXTENSION.

Since the restitution of length and alignment depends on the maintenance of an adequate extending force over a period of at least six weeks, it is of the utmost importance to preserve the integrity of the skin. This depends primarily on the dragging force applied to it, and the distribution of that force over as wide an area as possible affords the best chance of avoiding the blistering which is the chief difficulty in mechanical treatment.

Methods of extension.—The following adhesive methods are of value:

Ordinary adhesive strapping. This is a very satisfactory method for fractures of the femur, as it is the least irritating to the skin, and when it slips, slips slowly. The skin is first shaved, grease is removed by soap and water followed by spirit, and the limb is thoroughly dried. Care in avoiding wrinkles when applying the plaster is well repaid, and a narrow strip of wool along the crest of the tibia prevents pressure sores developing when the leg wastes.

Glue used according to Sinclair's methods is of great value on account of its cheapness and rapid application. The skin is not shaved, but all grease is removed by washing with a weak solution of sodium bicarbonate. The disadvantages are a tendency to blister the skin and to slip suddenly. On account of its great holding power it is the best adhesive to use when small areas of skin only are available.

Special methods of extension dependent on the use of glue are Sinclair's foot piece and plaster of Paris sole skate. In the former, traction is taken from the dorsum and sides of the foot, in the latter, a plaster cast is glued to the skin of the sole.

An adhesive with advantages and disadvantages similar to those of glue is a solution of resin and venice turpentine in a mixture of benzine and spirit.

Direct traction on bone.—Finochietto's stirrup: This is a flat steel spring introduced between os calcis, tibia and tendo achillis, and attached at the ends to a rigid steel stirrup through which extension is applied.

Traction by "tongs."—Transfixion pins have been used. On account of the danger of infection of the knee joint it is not advisable *to transfix the condyles* of the femur. Instead of using the transfix-

ion pin, extension has recently been applied by means of small steel "tongs," shaped like "ice-tongs." The points of these are fixed just above each condyle of the femur, with proper aseptic precautions. It is of the utmost importance that in fixing them into the condyles the greatest care shou'd be taken to avoid injuring the lateral reflections of the synovial membrane. They are specially useful for fractures just above the knee. These various mechanical devices are chiefly of use when extension by adhesive measures is impossible.

Massage.—As soon as recovery from the journey has taken place systematic attempts should be made to maintain the general muscular condition of the patient and the mobility of the joints of the injured limb, and these are interrupted only during periods of recrudescence of sepsis, or recovery from operation. For example, a man with a fractured femur is given an overhead support by which he can pull himself up in bed and exercise his arms, he is encouraged to sit up for meals and to keep his ankle mobile. He receives daily massage to the sound leg and to the synovial membrane of the knee on the injured side, provided that the joint is not involved. As soon as the fracture becomes firm, the extension is relaxed and the knee moved daily.

FRACTURES OF THE UPPER LIMB.

Whenever feasible, ambulatory treatment is commenced as soon as the temperature is normal. If fixation with a straight elbow be necessary in the interests of the fracture, movement of the elbow and radio-ulnar joints is begun at the earliest possible opportunity without waiting for consolidation of the fracture.

Humerus—Elbow flexed.—A simplified type of Leclercq splint such as the Gray-Depage or Hey Groves is very satisfactory, or, if more support is required for the forearm, Jones' modification of the Thomas arm splint. These splints are suitable for fractures of the lower third, and those of the middle third without axillary wounds.

Elbow straight.—Where access to large wounds is necessary, and in fractures of the upper third where the pull of powerful muscles leads to displacement of the upper fragment from the anatomical position, the swivel arm Thomas splint, with weight and pulley extension is the most useful. It may be supported comfortably from "Sinclair's arm suspension" with the extension weight hung from a separate upright screwed to the floor. The average weight required for extension is 6 lbs. The patient is propped up with a bed rest, and the posi-

tion of the limb is fixed under radiographic control. As a rough guide, fractures immediately below the axillary folds require 60° flexion of the shoulder joint without abduction, while those of the surgical neck are reduced in a position between the above and 90° abduction.

Forearm.—Fractures of the forearm, whether one or both bones are involved, *are treated in a position of full supination*, as supination is the movement most readily lost. A simple, but efficient, splint is a skeleton wire frame enlarged at one end to take the hand, with a right-angled bend at the elbow to which is attached a curved tin plate taking counter extension against the lower end of the biceps. A glue extension fixes the hand, or wrist, to the other end, and the whole is supported by a sling.

FRACTURES OF THE LOWER LIMB.

Femur.—As a rule fractures of the thigh arrive at the base in a Thomas splint, and may be efficiently treated by this type of apparatus throughout, except when the ring is in immediate contact with the wound. It is desirable not to immediately move the splint in which the patient has been sent down unless this is really necessary. The Thomas splint is invariably bent opposite the knee, and the foot is supported by a sling glued to the sole, or by any other method which allows free movement of the ankle. The limb is supported in the splint by slings of linen, or flannel, fixed by large paper clips.

Suspension.—The whole splint is then slung, preferably by weights and pulleys, to an overhead support of the Sinclair, Balkan, or American type.

Extension.—Extension may be by the weight and pulley, inclined plane, or by "fixed" traction, the results obtained by each in experienced hands being identical.

Weight and pulley.—The standard weight required is 20 lb. with the foot of the bed raised 12 inches to provide counter-extension by the trunk.

When adhesive methods are employed, one-third of the total weight required may be applied at the start and quickly raised to the maximum. If the full weight is applied at once there is risk of *blistering the skin*. As soon as union occurs the weight is reduced to *half; this is maintained* for a further two weeks, and then omitted *altogether*.

Inclined plane.—In using the inclined plane the distal end of the Thomas splint is fixed to a bar at a suitable height from the floor, and the foot of the bed is raised 12 to 15 inches. It will be noted that in the two methods described above the Thomas splint is really used on the Hodgen principle. Its advantage over the original Hodgen splint lies in the greater stabillty and ease of transport afforded by the ring.

"Fixed" extension.—In fixed extension (the method used by Thomas) counter-extension is provided by pressure of the ring of the splint against the skin covering the ischial tuberosity. It is not nearly so satisfactory as extension by weight.

The mechanical treatment of the fracture is carried out in two distinct stages:—

(1) Reduction by manipulation and over-extension.

(2) Maintenance of the corrected position by daily tightening of the extension as the skin stretches or the strapping slips. This may be done by pulling down the extension strips and tying them to the ends of the splint, or, by fixing them to a wooden spreader which in turn is attached to the end of the splint by a strap and buckle. If "fixed" extension is used the skin over the ischial tuberosity is treated like that of the back to avoid pressure sores.

Foot drop.—Foot drop may develop at any time after the first week, and is due to pressure on the external popliteal nerve by the sling immediately below the knee. It is always preceded by pain in the ankle and foot. As this particular sling is of great importance in maintaining flexion of the knee, it is advisable to protect the region of the head of the fibula by a small wool ring rather than by relaxing the sling. At the first complaint of referred or local pain, any adhesive over the neck of the fibula is removed and a wool ring inserted.

A sectional mattress is convenient for obtaining access to posterior wounds.

FEMUR—UPPER THIRD.

Deformity.—The upper fragment is abducted by the small gluteals and flexed by the psoas. If the lesser trochanter is separated from the upper fragment, flexion of the latter does not occur. As the upper fragment is too small to be controlled the lower fragment must be brought into line with it. In subtrochanteric fracture the deformity is corrected when the injured thigh makes an angle of about 90°

with the horizon and about 80° with the opposite thigh. Abduction may be obtained either by fixing and abducting both thighs, or by fixing the injured side and tilting the pelvis by means of a perineal band round the opposite groin.

If the position of the wounds permit, the most complete control is afforded by suspending each lower limb in a Thomas splint with 30° flexion at the knee, and abducting one from the other until there is an angle of 80° between them. Flexion at the hip is obtained by propping up the trunk. Extensions used: Adhesive above knee, pulling in line of thigh; adhesive below knee and sole skate attached to end of splint. Total weight 20 to 23 lbs.

Hodgen splint.—The Hogden splint is well known. It gives excellent results and is particularly useful when a high wound interferes with the application of a Thomas splint.

Sinclair's "net frame" is a rectangular wooden frame in which the patient is supported by a strong net. Each lower limb is attached to its corresponding corner of this net. The frame is suspended by ropes from overhead bars, and the foot end is raised till the necessary extension is obtained.

Bryan bed.—The "Bryan bed" is composed of two Balkan supports joined by transverse bars at head and foot. The patient is supported by broad flannel slings stretching from side to side. Abduction is secured by slinging the injured limb from an adjustable overhead bar. Correction of the deformity with this apparatus requires considerable practice.

Jones abduction frame.—The Jones abduction frame has not proved suitable for gunshot fracture on account of the difficulty of carrying on the treatment of the wound. Abduction is secured by tilting the pelvis by means of a perineal band on the opposite side. Extension is of the fixed type. It does not allow correction of the flexion of the deformity.

Hey Groves splint.—The Hey Groves splint is a skeleton double inclined plane of wire with weight and pulley extension. Abduction is maintained by a perineal band round the opposite groin. The splint is adapted primarily for use with a transfixion pin through the lower end of the femur.

FEMUR—MIDDLE THIRD.

Shortening may be overcome by axial traction in a straight Thomas splint, but greater comfort and more perfect alignment can be

secured by bending the knee 30° The tension of the slings is adjusted so that the convexity of the anterior surface of the sound thigh is reproduced on the injured side. Extension used: Adhesive below knee and sole skate. Total weight 18 to 20 lb.

FEMUR—LOWER THIRD.

Deformity.—The pull of the gastrocnemius begins to produce backward displacement of the lower fragment when fracture occurs, even at a short distance below the middle of the shaft, and this "flexion deformity" increases progressively as the point at which the bone is broken approaches the knee.

The deformity may also be reduced by means of a Thomas splint with 45° flexion at the knee, and a special sling to lift the lower fragment into position. This sling may be attached to a third bar running from the centre of the anterior half of the ring to a wire foot support attached to the side bars of the splint at the level of the knee. Extension used: Adhesive below knee, sole skate (if required). Total weight 15 to 16 lb.

Another method of correcting the deformity is by applying traction to the condyles of the femur with the "ice tongs" calliper alluded to on p. 67. The knee should be kept semi-flexed.

Union may usually be expected to commence in the fifth week, but it is advisable to maintain extension for at least two weeks after the commencement of consolidation, especially in subtrochanteric or grossly infected fractures, on account of the liability to recurrence of deformity.

Ambulatory treatment.—As soon as consolidation is established and the condition of the patient allows, he is fitted with an apparatus which enables him to walk without throwing any strain on the fracture, the weight of the body being taken on the ischial tuberosity.

Calliper splint.—The Thomas calliper splint is the standard apparatus used for this purpose, and is made by fixing the side bars of a straight Thomas splint into the heel of the boot after cutting them to such a length that a space of ½ inch is left between the skin of the heel and the inner surface of the boot.

Page has designed a simple apparatus which leaves the knee free. It consists of two moulded plaster of Paris collars, united by two ex-

tension screws. The upper collar encircles the thigh at the level of the tuber ischii, the lower immediately above the femoral condyles.

TIBIA AND FIBULA.

All fractures of the leg are conveniently treated in a Thomas splint with bent knee. In those of the lower third where the bone ends are widely exposed, care is required to avoid over-extension.

FRACTURES INTO JOINTS.

The condition of the joint is an important factor in the treatment, which should follow the lines indicated in the section dealing with wounds of joints. Suppurative arthritis of the knee complicating fracture of the femur or tibia often requires amputation. In the case of other joints conservative measures are more likely to succeed.

Section X.—INJURIES OF JOINTS.

TREATMENT OF WOUNDS OF JOINTS.

KNEE JOINT.

Wounds of the knee-joint are more frequent and liable to be more disastrous in their consequences than those of any other joint. Their treatment, therefore, will be described, and the principles advocated can be adapted for other joints.

Nature of the injuries.—In the treatment of these cases there has been very great improvement since the early days of the war. This is owing to the fact that most operations are performed before sepsis has become established, to the thoroughness with which they are carried out, and also to careful fixation during transport. In many of these cases delay in operation means disaster, for the nature of the injuries and of the infection, coupled with the unfavourable conditions under which the wound is received, give rise to such an exceedingly rapid inflammatory disintegration of the joint and breakdown of the patient's general resistance, that amputation may become the only means of saving the patient's life.

Types of injury.—Certain common types of injury may be summarised:

(1) Cases of effusion without lodgment of the projectile in the joint: (*a*) in which it is uncertain whether the synovial cavity has been traversed, or the synovial membrane has been merely bruised; (*b*) in which the synovial cavity has been traversed by a clean rifle bullet without injury to the bones; (*c*) in which the bullet has cleanly perforated one of the bones entering into the articulation.

In connection with injuries of this class, the common association of effusion into an intact knee-joint with a fracture of the shaft of the femur is to be borne in mind.

Cases included in Class 1 are obviously suitable for expectant treatment.

Hæmarthrosis with small external wound.—If the effusion is considerable and its tension causes pain the joint may be tapped, but, if the fluid cannot be aspirated, owing to the fact that firm clotting

has occurred, good results will be obtained by deliberately opening the joint, washing out the clot, and stitching up again without drainage. If the wounds are very small, it is only necessary to sterilise them superficially, unless they come in the line of the incisions, when they should be completely excised. If there is reason to suspect infection of the effusion, the joint should be tapped, and the blood or synovia examined bacteriologically. If few and non-virulent organisms are found, the joint may be opened and washed out thoroughly with some warm non-irritating antiseptic, and then closed.

(2) *Retained missiles.*—Cases in which the projectile has lodged (*a*) within the synovial cavity, and (*b*) in one of the articular ends of the bones.

When a retained rifle bullet lies within the joint, if the superficial wound is small and not inflamed, it may be left for a few days, the joint being meantime immobilised, but the better plan is to take no risks and to operate immediately.

Free fragments of shells or bombs or distorted rifle bullets must be promptly removed.

Missiles embedded in the bones.—Bullets or shell fragments embedded in the articular ends of the long bones form a difficult problem. Clean rifle bullets, so situated as not to interfere with the movements of the joint, need not be interfered with at an early stage. They may do no harm, and have frequently been left indefinitely. Fragments of shell, unless very minute, come into a different category. Here infective material has practically always been carried in, and the retained body must be removed (*see* p. 76) by the shortest and safest route. This should generally be by the original wound.

(3) *Open wounds of the joints.*—Cases in which the synovial cavity has been more or less widely opened (*a*) without damage to the articular surfaces, and (*b*) where fissured fracture or slight comminution of the articular ends of the bones co-exists.

These require the primary measures which are detailed later on, and often make remarkably good recovery if operated on within 12—24 hours.

(4) Cases in which extensive comminution of one or more of the constituent bones has occurred.

Seriously comminuted fractures.—The majority of cases in which *gross comminution* and soiling of either femur or tibia is present *require amputation.*

TREATMENT AT THE FRONT.

AT REGIMENTAL AID POSTS AND FIELD AMBULANCE DRESSING STATIONS.

All these injuries should be treated on the same lines as fracture of the femur, that is to say, they should be put up in a Thomas splint. The skin should be painted with picric acid, and the wound lightly dressed with gauze wrung out of some weak antiseptic lotion. No drainage tubes should be inserted. Dressings and bandages must not be applied so firmly that the circulation of the limb or exudation from the wounds is interfered with.

Movements of the joint at this stage may turn the scale in favour of extension of sepsis and may make all the difference to the patient's future.

AT CASUALTY CLEARING STATIONS.

The good results which can be achieved by early operation make it desirable that all cases in which this is necessary should be treated within a few hours of admission, but during severe fighting this is not always possible, so that a selection may have to be made of cases likely to be able to travel to the base without serious risk.

This selection, as far as the injury of the joint alone is concerned, will depend chiefly on the size and position of the wounds, especially of entrance wounds; on the size and character of the missile, especially if lodgment has occurred, and on whether it is visible or palpable; on the size of the wound in the synovial membrane, and on whether it communicates freely with the surface wound so that infection will occur easily; on the amount and character of comminution of bone; on the presence or absence of injury to large vessels; on whether intraarticular tension is present or absent; and, finally, on whether definite sepsis has developed or not.

Cases for transfer to base.—If the wound of entrance is small, especially if due to an undistorted rifle bullet, if there is no external evidence of a foreign body, if there is no comminution of bone or injury to large vessels, if there is not painful tension, and if there is no inflammation, the patient may be sent on to the base, after thorough disinfection of the skin, suitable dressing of the superficial wounds, and fixation of the limb, the knee being slightly flexed, in a splint of *proper* length. The Thomas splint is the best for the pur-

pose, and it should be employed in all cases in which penetration of the synovial cavity is even suspected.

An "open" wound of the back of the joint is usually more suitable for transport than a similar one on the anterior aspect.

Cases for retention at C. C. S.—If the superficial wound is large, and especially if it communicates freely with the synovial cavity, if there is a visible or palpable foreign body which has opened the joint, if there is much comminution of bone, if there is a hæmatoma in the popliteal space or hæmorrhage from a wound there, or if there is already severe arthritis, the case should be kept at the casualty clearing station.

If X-ray localisation is required, two skiagrams should be taken, one antero-posterior (toes pointing straight forward) and one lateral, on the same plate if possible. This method is probably the quickest and best in the circumstances. The patient is then sent to the preoperation ward. If an operation is to be performed the splint should not be removed till the patient has been anæsthetised.

General remarks regarding operation.—The surgeon who exhibits the greatest care in technique, especially when removing foreign bodies and infected tissue, whether of the soft parts or of bone, gets the best results, and operations on gunshot wounds of the knee-joint demand the care of the most experienced and skilful surgeons. Many failures are attributable to want of appreciation of what is essential in totally excising the soiled wound.

Excision of wound.—The ultimate object of treatment is to secure mobility of the joint. The primary object must therefore be to secure asepsis. The surest and quickest way of doing this is to excise completely (if possible *en masse*) all tissue which is definitely or probably infected. This having been done, the wound remaining can be treated on aseptic principles.

Careful asepsis necessary.—All instruments, gloves, towels, etc., which may have come into contact with infected parts, should be removed after the excision is completed. The wound in the synovial cavity is then carefully sutured, and in most cases the skin closed.

No drainage tubes in the joint.—It is advisable in some cases to provide drainage down to, but not into, the joint cavity for 24 hours.

Although cases occur in which the wounds cannot be closed, yet it is usually possible to suture the synovial membrane of the front of the joint, especially if the suprapatellar pouch is loosened from its upper and anterior connections, and pulled down. In order to

close the wound a plastic operation may be necessary. Wounds through the posterior ligament cannot be sutured.

Fixation.—Fixation of the joint after operation is essential to success, even in the simplest wounds. The best method of ensuring this is to put up the limb, slightly flexed, in a Thomas splint, just as in cases of fracture of the femur, with the exception that the extension strips are applied with the object merely of keeping the Thomas splint in position. If a back splint only is used, it must reach from below the *tuber ischii to the ankle*. Shorter splints are worse than useless.

Foreign bodies.—Removal of a foreign body, lodged within or near the joint, and not visible or palpable from the surface, should not be attempted without X-ray localisation when that is available.

Amputation.—If the injury has implicated the main vessels so that the foot is already cold and dead, amputation should be done, just above the knee if the wound is likely to remain fairly clean, and through the knee if sepsis is present and the condyles undamaged. In the latter class of cases re-amputation is usually necessary. If one or other popliteal nerve is shot away so extensively that it cannot be sutured later on, and if the bones are much soiled as well as comminuted, primary amputation is the best course. If sepsis is well established in presence of much comminution, especially if there be gas gangrene, amputation must be done.

Conservative treatment of fracture cases.—If there is no serious comminution of the femur or tibia, if the patient has been brought in early and is in good condition, and if the surgeon is satisfied that a satisfactory excision is possible, the case should be treated on conservative lines.

Primary excision of the joint.—Early excision of the bone ends for comminution of the femur or tibia, if not too extensive, and before sepsis has occurred, has established itself as a sound method of treatment. In this case the sawn ends may be brought together with every prospect of bony union and a useful limb. The synovial membrane resembles the peritoneum in its resistance to infection, and should be disturbed as little as possible.

Removal of patella.—As a general rule, if the patella alone has been shattered, the fragments should be removed. If possible, the synovial cavity should be closed by suturing the lateral edges and aponeuroses, possibly after undercutting the synovial membrane on each side, or by loosening the suprapatellar pouch, as

already described. The same procedure should be carried out if concomitant injury to other bones is not extensive. It is noticeable that the infection tends to remain limited to the anterior part of the joint if the limb is thoroughly immobilised.

Conservative treatment.—When conservative measures are decided upon, the following are the most important operative details:

(1) Determination of the track which leads to the joint. The knee may have been bent when the patient was wounded, so that, when the limb is straight, the track is distorted. Excision of the track is best made when the knee is held in the same position as when injured.

(2) Thorough disinfection of the skin and track. The whole of the skin around the wound for at least 6 inches above and below the knee should be shaved, washed, and disinfected by picric acid (3—5 per cent.) in spirit. The external wound and track may be disinfected (*a*), if not very large, by the actual cautery, or (*b*) by rubbing thoroughly every part with 10-per-cent. iodine or picric acid in spirit. The strong solution has the effect of drying the tissues.

(3) Careful and complete excision of the external wound and track, including the edges of the wound in the synovial membrane, if possible, in one piece. Incision, using a sharp scalpel, must be made quite clear of the deep as well as clear of the superficial wound. Pockets must not be cut into. The knife should be used rather than scissors. A very little infected tissue left behind may prevent success.

(4) Provision of ample access to foreign bodies or comminuted surfaces in the joint. Blind groping with the finger is to be avoided, because the foreign body or infected material is thus frequently pushed beyond easy reach. Incisions must be chosen, therefore, which give easiest access, and they must be free enough to enable the surgeon to *see* the foreign body, and obtain plenty of room for manipulation of instruments. If the missile is impacted, the bone surrounding it must be carefully chiselled or gouged away *en masse* if possible. The joint should then be flushed out; cavities in the bone may be treated with B.I.P.P. or some other paste. If complete excision of the infected tissues has been made under proper *technique,* healing by first intention may often be obtained, even *when the wounds are large,* by suturing the synovial membrane *with fine catgut and subsequently* closing the skin.

(5) Drainage tubing, if used, should not project into the joint. If tubes are required for the Carrel-Dakin method, they should be carried to the deepest recesses of the joint, or inserted through a fresh incision. They should be removed as soon as possible.

(6) If the wound in the synovial membrane cannot be closed, gauze wrung out in saline solution or in iodoform paraffin, and separate from that which may be required for the rest of the wound, should be gently inserted down to the joint capsule, and should be left until it is absolutely loose. A small tube may be also employed for about two days.

(7) Tendinous or ligamentous structures exposed during operation should be covered in by skin and subcutaneous tissue, otherwise they are very apt to slough and delay closure of the wound.

(8) If there is much effusion into or from the joint, or if raw surfaces, whether of bone or soft tissue, are exposed in the articulation, a tube should always be inserted as far as the joint capsule. Tension must be avoided, because it interferes with healthy circulation in, and absorption by, the synovial membrane, and these are essential to successful combatting of infection.

(9) The injection of ether, formalin-glycerine, or hypertonic (5 per cent) saline solution into closed joints is of doubtful value. They are all irritants. Success is claimed for all three, although their actions are different.

Treatment and retention of cases after operation.—Patients who have been operated upon in a casualty clearing station should be retained for at least 24 to 48 hours. If then the joint looks quiet and the general condition is good, many can be evacuated with safety, but in more serious cases evacuation should be postponed, if possible, till all danger from sepsis has passed. Firm compression under a very thick layer of cotton wool should be employed in the early stages. The knee should be slightly flexed and supported by a pad of wool in the popliteal space.

If there is a large wound on the posterior aspect of the knee, the thigh and leg should be suspended on separate slings of perforated zinc, well padded and covered with jaconet, so that access to the wound is provided without running the risk of moving the joint.

Gentle passive movement, to a few degrees at first, should be begun as soon as it is clear that the parts are healing aseptically.

SPECIAL REMARKS ABOUT OTHER JOINTS.

Experience has shown that formal resections of injured joints should seldom be performed, and that better functional results are usually obtained by more conservative treatment, for many flail limbs have followed resection.

It is generally advisable therefore only to remove badly shattered bone, either for the purpose of obtaining efficient drainage or else with the object of excising fragments that are likely to necrose or to maintain suppuration.

The same care should be exercised in dealing with fractured articular ends as has already been described in dealing with fractured bones in general, and the greatest care should be taken to leave as clean a wound as possible. If the functional result proves unsatisfactory, excision can be subsequently performed.

If there is no fracture of articular bone, but only a wound of the soft tissue opening the synovial cavity, the wound may be closed after the usual surgical cleansing has been carried out.

Shoulder joint.—If the head of the humerus is shattered, the fragments should be removed, but it is very desirable not to remove bone further than the surgical neck, as a flail limb is very liable to result from such excisions. After operation the limb should be kept in a position of abduction, so that if anchylosis occurs the arm may be at the best angle for usefulness.

Fractures into the elbow joint.—In these fractures it is common to find both the humerus and one or both of the bones of the forearm involved. There is often much comminution and loss of bone, so that by the time all loose fragments have been removed much of the articular bone has been lost. It is in such cases that the advisability of a primary excision is raised, but a formal resection of the joint is seldom advisble, and it is better not to remove more bone than is necessary. The results of primary excision have not been good, and in many of the cases a flail joint has resulted and has caused a very limp and useless arm.

These cases, after operation, may be put up either on the Thomas splint, or else on the "Jones elbow splint."

AT THE BASE.

Wounds into the knee-joint should be closed.—The cases that arrive at the base fall into two categories, those that have been operated on and those that have not. Improved technique is responsible for a remarkable change in the history of joint injuries at the base. The results at the present moment are infinitely better than those seen at the beginning of the war. It is a rare occurrence now to see a case of open knee-joint arrive at the base. Added to careful technique, such as excision of the track of the missile, removal of blood clot, clothing, loose fragments of bone, and foreign bodies, there can be no doubt that the practice of accurately suturing the synovial membrane after operation has been largely responsible for this improvement. Even in cases of bone injury this closing of the joint without drainage has given results of a most satisfactory character. Of the cases operated on at the front in the manner indicated a small proportion still go wrong, but the numbers are steadily diminishing.

A certain number of cases which have escaped operation reach the base. Most of them are through-and-through bullet wounds with or without injury to the bone, which the surgeons at the clearing stations have judged suitable for expectant treatment. In a rush, however, it is common to receive also wounds produced by shell.

Cases with small bullet wounds, through and through, and apparently clean, should continue to be treated on the expectant plan unless signs of infection declare themselves, when they must be dealt with according to one of the methods to be described later. Shell wounds and bullet wounds with retained foreign bodies are treated as far as possible on the same lines as at the clearing stations. But it must be remembered that very often the pre-inflammatory stage has passed, and manipulation, such as that required for the removal of a foreign body, shreds of clothing, or fragments of bone, is attended with greater risk of the spread of infection than in the earlier period. Bullets or fragments of metal, free or projecting into the joint, are generally removed, but it is open to question whether foreign bodies deeply embedded in a bone in a case which shows no sign of active mischief should not be left at this stage. Here individual judgment and experience will decide what course is to be followed.

Infective arthritis.—The surgeon will not long be in doubt as to the course a given case is about to take. If infection is present, the pulse and temperature will rise, the suprapatellar pouch will become distended, or fluid will exude from the original wound or the operation wound, tenderness will be found along the line of the articulation, and œdema, generally more marked just below the joint, will make its appearance. This œdema is a constant feature in infected cases, and is an indication that all is not going well. As soon as any distension of the joint is noticed, fluid should be removed by a syringe for diagnostic purposes, and the presence and nature of the infection determined in the laboratory. It will be found that the most usual and most serious infections are streptococcal. Anaërobic infections occur, but they have not the same significance as in fleshy parts unless they are associated with streptococcal infections, as sometimes happens. Staphylococcic infections are of less importance and more likely to localise themselves than streptococcal. Infection by other microbes occurs, but the above mentioned are the most usual. The subsequent course of the case will depend on the virulence of the infection, the resistance of the patient, and the presence or absence of bone lesions. Injury to bone adds greatly to the risk. The treatment of established infection of the joint depends so much on the individual case that no general rules can be laid down.

Fix the joint by a Thomas splint.—Among British surgeons one of the first principles in the treatment of knee-joint injuries is the maintenance of absolute fixation, generally by means of a Thomas splint. For the relief of pain it is a common practice to apply extension, so as to relieve the pressure on the articular ends of the bones.

Aspiration.—In a certain proportion of infected cases, aspiration of the joint cavity may be sufficient. This may have to be repeated several times. Some surgeons irrigate the joint through the aspirating needle, or insert a second, and wash from one to the other. It must be remembered that irrigation under tension may break down protective adhesions, and may, in addition, drive infected fluid into recesses and diverticula as yet unaffected. Further, blood clot or masses of fibrin cannot be removed by this means.

Arthrotomy with immediate closure.—As an alternative to the above or following it, the joint may be opened up, cleared of débris, fluid and blood clot. Gentle irrigation may now be carried out, and the joint closed without drainage. Some surgeons, following Rutherford Morrison, *dry out the* cavity with spirit, rub bismuth, iodoform and

paraffin paste (B.I.P.P.) into the joint surfaces, remove the excess, and close the joint with interrupted sutures. In the majority of cases these methods will fail, and more radical measures will be required.

Open arthrotomy without tubes.—In some cases it may be sufficient to make incisions on either side of the patella at the lateral limits of the suprapatellar pouch. Gauze may be placed in the lips of the wounds so made but should not project into the joint. The practice of placing drainage tubes in the joint has been almost entirely abandoned, as the results in the early days of the war were disastrous.

Carrel's method.—The method of treatment which finds most favour is the Carrel-Dakin. After arthrotomy, Carrel's tubes are introduced into all the recesses of the joint, and careful irrigation is carried out every two hours with Dakin's fluid. It may be necessary to make posterior incisions in order to reach the condylar pouches, or even in bad cases to divide the lateral ligaments. The tubes should be removed at the earliest possible moment, the time of their removal being determined by bacteriological examination of smears from various parts of the cavity. If a decided improvement is not soon apparent, and the patient shows signs of grave constitutional disturbance, it is better to amputate at once before he becomes too much exhausted.

Division of lateral and crucial ligaments with acute flexion of the joint.—This procedure was at one time fairly commonly practised The object is to reach and drain the posterior limits of the joint. It is a severe operation, and may require to be followed by excision of the joint. This method has still a few adherents, but the majority of surgeons have abandoned it.

The success of any of the foregoing methods of treatment will sometimes be greatly prejudiced by the occurrence of abscesses tracking in the leg or thigh. The most frequent situation is in the calf, the infection tracking along the tube of synovial membrane surrounding the tendon of the popliteus. A careful watch should be kept for pus formation here, as, on account of the depth of its situation, it is liable to escape notice until much swelling of the calf has taken place.

Secondary excision.—When sepsis has become established, and especially when the presence of bone injury renders it difficult or impossible to accomplish surgical sterilisation of the joint, the question of a formal excision will arise. It would appear sound policy in

these cases to remove bone, first, in order to get rid of infection in the bone itself, and second, to convert a highly complicated cavity into a simple one for drainage purposes, the sawn ends being held apart until sepsis has been controlled. The after results, however, have not been so good as had been hoped for. Many flail joints have been reported, even after the lapse of six months. In addition, in a considerable proportion of cases, sepsis has remained uncontrolled in the soft parts, and amputation has had to be performed. On the other hand, in some cases sound bony union and a useful limb have resulted. The results are better if the cases remain under the care of the surgeon responsible for the operation until the fate of the limb is decided. If excision of the joint for sepsis is to be done at all it must be done early and before pus has broken through the synovial membrane. Selection of suitable cases requires much judgment and experience. The surgeon should keep the case under his own care until either sepsis has been controlled, the bone ends brought accurately together, and the wound in the soft parts closed by secondary suture, or until he finds that failure to control sepsis necessitates amputation.

Amputation.—Amputation should be performed when a fair trial of conservative methods has failed to control sepsis. In fulminating cases, with a high temperature and a rapid pulse, in a patient obviously gravely ill, especially if bone injury is present, amputation to save life is imperative.

In any case, if blood cultures demonstrate the onset of septicæmia, it is dangerous to persevere with conservative methods.

Secondary hæmorrhage is likewise a contra-indication to persistence in efforts to save the limb.

In less severe cases, if there be much tracking of pus, or if the patient is losing ground, as evidenced by wasting, increasing anæmia, continued pain and loss of sleep, and loss of appetite, amputation should be performed. It must be remembered that a serious illness lasting many weeks is not compensated for in the long run by saving a limb if irreparable damage has been done to the patient's organs and tissues by prolonged suppuration and fever.

Injuries of various joints.—The treatment of infected joints other than the knee is conducted on similar lines. It will be understood, of course, that amputation in the upper extremity is much more disabling to the patient than in the lower extremity. Even a severely crippled upper extremity is of more use to the patient than

the most elaborate artificial substitute. One is frequently driven, therefore, to perform excisions for drainage with the full knowledge that the orthopædic result is likely to be far from perfect.

Joint drainage.—In the case of the hip it may be impossible to drain the joint without removing the head of the femur. The results of this procedure as regards the subsequent use of the limb have been far from satisfactory, but amputation through the joint has been attended with such a very high mortality that surgeons have chosen the less of two evils. In the case of the ankle, removal of the astragalus has sometimes saved the foot. Bad smashes of the tarsus with severe infection are probably best treated by amputation.

Section XI.—HEAD INJURIES.

Patients with injuries of the head have shared in the benefits which experience and the opportunities afforded by stationary warfare have conferred upon the wounded in general. Improvements in surgical technique, together with the remarkable increase in the facilities for its application, are enabling these cases to be treated efficiently at a much earlier stage than was formerly the case. Although, so far, no large series of cases is available which points to marked decrease in mortality, yet there are indications from the cases of a number of individual operators that diminution in mortality and improvements in results are occurring.

Another factor has contributed in a remarkable manner to the relatively diminishing number of badly septic brain cases. This is the steel helmet, one of the outstanding effects of which has been to reduce the proportion of penetrating as compared with non-penetrating wounds, and this fact brings into still further prominence the importance of an intact dura mater, and the need for respecting its integrity, to which attention is drawn below.

Nature of the injuries.—Apart from scalp wounds, the majority of gunshot wounds of the head are essentially compound fractures complicated by more or less serious injury to the brain and its membranes. The nature and extent of the damage to scalp and bone, and the presence or absence of a foreign body can be ascertained by inspection and X-ray examination, but the extent of the cerebral injury can be definitely determined only by evidence of disturbance of cerebral functions and a consideration of the factors that contribute to it.

Symptoms of injury to the brain.—Some of the symptoms of injury to the brain are only temporary, such as the effect of shock, or of contusion, while others are due directly to the destruction of brain tissue, and vary according to the region injured.

It is apt to be too readily asumed that the symptoms which may exist at any given moment after receipt of the injury are related directly to some gross and visible lesion, such as depressed bone or hæmorrhage. This assumption is likely to lead to the performance

of an operation, having for its object the amelioration of the symptoms. In many cases such an operation is destined to fail, because the functional disturbance is frequently not due to any pathological condition that can be directly affected by the operation. The blow which has injured the scalp and bone has also, and at the same time, injured the brain; the lesions are co-existent but independent.

Infection.—Later, another factor may come into play, namely, microbic infection. The importance of this factor is almost wholly dependent upon the integrity of the dura mater, and so vitally important is this membrane as a barrier against intracranial infection that it is rarely justifiable to incise it in the presence of an open wound.

Importance of the barrier afforded by the dura mater.—In many cases of gunshot wounds of the head the dura is already lacerated, but, in spite of this, the subarachnoid space often escapes direct infection owing to the rapid formation of adhesions between the dura and the pia-arachnoid round the opening. Any enlargement of the dural opening, therefore, in the course of an operation is liable to be followed by the spread of an infection, and should be resorted to only in exceptional conditions. Fortunately, in most cases, any intracerebral procedure which may be necessary for the removal of bone fragments, and for the drainage of the disintegrated and septic brain along their track, can be carried out quite well through the original opening in the dura without disturbance of these protective adhesions.

Objects to be attained by operation.—Before undertaking any operation it is desirable to have a clear idea as to its aim, what result is to be expected from it, and how best that result is likely to be attained. The operative objectives may be: (1) The cleansing of the wound and removal of bone fragments and missiles; (2) the relief of symptoms of cerebral injury; and (3) the prevention of complications which might arise in future. We may briefly examine each of these proposals.

Nature of cranial operations.—(1) *The cleansing of the wound.*—It is this which should always be regarded as the primary object of any operation for gunshot wound of the head. In general it may be said that the sooner such proceedings are undertaken the better, provided that the circumstances are such that the operation can be done thoroughly and efficiently. Hurried and incomplete operations at *an early* stage have given worse results than operations carried out

with more deliberation and in better surroundings, even though a day or more may have elapsed since the wound was infected.

(2) *Relief of symptoms of cerebral injury.*—These symptoms may be general or local. The most prominent of the *general symptoms* are loss of consciousness, headache, slowing of the pulse rate, and (often quite early) blurring of the optic discs. Do these symptoms, which are due to a pathological increase of intracranial pressure, need immediate relief by operation? The answer becomes clear when the underlying pathological basis is considered. Within the first two or three days the rise of pressure is due to contusion, usually associated with small hæmorrhages in various situations both intracerebral and extracerebral and with œdema. These lesions are not confined to the neighbourhood of the injury, for "contre-coup" contusion is very common, and small hæmorrhages are frequently found scattered throughout the brain. The latter, in fact, is bruised and œdematous, but the pressure so produced is rarely sufficiently high to require relief by operation. Occasionally a progressive hæmorrhage may cause an increasing rise of pressure, but this is rarely met with in gunshot wounds, and when it does occur it gives rise to unmistakable signs, such as deepening coma, muscular flaccidity, slowing of the pulse rate, and stertorous breathing.

The prominent *local symptoms* commonly observed are paralysis, fits, alteration of reflexes, sensory disturbances, and visual defects; these are due either to destruction of cerebral tissue or to temporary functional disturbance by shock, contusion, local œdema and the like, which on the one hand cannot be influenced by operative interference, and on the other, tend to recover spontaneously. It is clear therefore that operation is very rarely called for merely on account of cerebral symptoms whether general or local.

(3) *The prevention of symptoms which might develop later*, and especially of focal epilepsy, has often been the direct object of an early operation. Such evidence as has at present accumulated points to the comparative rarity of epilepsy; moreover the fits are at least as common in patients who have been operated upon as in those who have not. In these circumstances, the risks which attend intracranial manipulations in the presence of a septic wound are such as to forbid the performance of an operation the sole object of which is the avoidance of some problematical future complication. The avoidance of septic complications is more important, but comes under the next heading.

Causes of increased intracranial pressure.—(*a*) During the earliest stage the increase is due to contusion and œdema, and is rarely sufficiently severe to need operative relief.

(*b*) Occasionally, but rarely, progressive hæmorrhage causes the rise of pressure. In such cases it may become necessary to open the dura freely and to evacuate the clot, but here the grave risk of infecting the subdural space should only be taken to save the patient from death by compression.

(*c*) Later, increased pressure and development of a progressive hernia may be due to infection of the brain or its membranes, taking the form of meningitis or spreading encephalitis. Local abscesses also occasionally occur within two or three weeks of the injury.

Use of lumbar puncture and contralateral decompression.—In view of the fact that the early rise of intracranial pressure is rarely of sufficient degree to require a decompressive operation, and that lumbar puncture will give at least temporary relief; that progressive hæmorrhage is in these cases a comparatively rare condition; and that when widespread infection exists the majority of cases are hopeless (local abscesses excepted) it is clear that an operation of decompression is rarely called for. When such is required, however, it may be done locally or contralaterally.

Risks of local interference.—The local operation introduces so great a risk of meningitis, as the dura has to be opened in the presence of a septic wound or around a septic hernia cerebri, that the advisability of performing a clean subtemporal decompression on the opposite side has to be considered. Good results have followed this operation on several occasions. A hernia should never be cut off. This practice has been almost uniformly fatal.

CLASSIFICATION AND TREATMENT OF CRANIAL INJURIES.

Although a certain amount of overlapping is unavoidable, it is possible to classify cranial injuries into certain groups:

(*a*) *Fissured fracture, or depressed fracture of the inner table without gross defect of bone.*—In the majority of these cases immediate trephining is not indicated and the treatment is that applicable to any dirty scalp wound. In many cases it is best to excise the bruised and septic edges of the scalp and to suture the wound, a provision *for drainage being* made only in cases which are to be evacuated at

once or which are already grossly septic. The rapid healing to be expected makes it possible to perform any further operation which may be necessary in an aseptic field.

(*b*) *Tangential wounds of the gutter type.*—These are best treated by excision of the scalp wound, and removal of bone fragments according to the extent of the injury. When the dura is intact it should not be incised, even in the absence of visible pulsation. Tension can always be relieved by lumbar puncture, whereas the risks of causing intradural infection, and of doing further damage to the bruised brain beneath, are very considerable.

When the dura is torn, it is usually the case that any indriven fragments can be removed easily, as in this type of fracture they rarely lie at any considerable depth. This is particularly the type of case in which the exposed lacerated brain should be completely covered in by a repaired scalp, lateral drainage being provided in these cases only when the operator cannot be reasonably sure of having cleansed the wound sufficiently for complete closure.

(*c*) *Single penetrating wounds of the cranium.*—These are of two varieties. In the one the missile has entered the cranial cavity together with, and almost invariably has passed more deeply than, the indriven bony fragments. In the other, the missile has bounced off after driving in fragments of the bone from the fracture caused by its impact. These two may conveniently be called respectively "penetrating wounds" and "impact fractures." Minor degrees of impact fractures may cause depression without perforation of the dura mater. As without X-ray examination it is impossible to ascertain the presence, extent or depth either of indriven bony fragments or of pieces of metal, any primary interference in the absence of such examination should take the form described below. At the same time it should not be forgotten that neurological signs often afford valuable information. The procedure may be more bold where good radiograms are available and where the neurological aspect of the injury has been properly considered. It is in these cases particularly that the necessity for a complete shaving of the head should be emphasized, since what appear to be single penetrating wounds not infrequently turn out to be exit wounds, the small entrance wound elsewhere having been overlooked in a tangled mass of bloody hair.

(*d*) *Through and through wounds*, in which the missile has traversed and emerged from the cranial cavity, are best treated by cleansing the entrance and exit wounds, and carefully watching for symptoms

of compression which may follow the concussion stage. In most cases where the skull has been traversed by a bullet, the brain is so extensively injured that the chance of survival is small; a considerable number of recoveries have nevertheless been seen.

Wounds of the large sinuses.—Operations upon fractures presumably involving these, should be undertaken with the greatest caution. Should severe hæmorrhage occur it should be treated by the application of muscle or fascia to the wounded sinus. Plugging of the sinus is liable to be followed by disaster. The flap is best taken from the outer side of the leg and this should be previously prepared before the operation is commenced.

Retained missiles.—Since the universal adoption of the steel helmet, a larger proportion of shell fragments are found either embedded in the bone or lying amongst the bone fragments and other débris just within the cranium than was formerly the case. There is no difference of opinion as to the treatment of such cases; the removal of the foreign body is only an incident in the "toilet" operation outlined below. Fragments of shell, rifle bullets, and shrapnel balls which lie at a more considerable distance from the aperture of entrance, are almost invariably more deeply placed than the indriven fragments of bone. Even in the most experienced hands aided by the best skiagrams and with such assistance as the electromagnet may occasionally afford, the removal of even comparatively deeply placed fragments is a matter of difficulty, whilst it is accompanied by the risks of adding injury and of spreading infection. Further, it is now well known that a line joining the entrance wound with the foreign body does not necessarily represent the track of the missile; such missiles not infrequently impinge upon the inner surface of the skull opposite the point of entrance, and bounce off at an angle into the brain. An exploration which follows the supposed line of passage would, therefore, sometimes pass through uninjured and uninfected brain, leaving the actual track undealt with.

There is evidence to show that the track of a missile becomes progressively less heavily infected as the foreign body is approached, for abscesses in connection with retained missiles more often occur in some part of the track nearer the point of entry than around the foreign body itself. Further, recent information has shown that secondary abscess, whilst uncommon in cases of retained missile, is at *least equally frequent* whether the missile has been removed or not.

Remote effects of retained missiles.—A large number of patients carrying bullets and shell fragments in the brain have now been under observation for considerable periods, that is from twelve months to over three years. A recent investigation of these patients shows that, in the great majority of cases, such foreign bodies cause no inconvenience. These considerations, added to the fact that, in the past at least, removal of deeply placed foreign bodies has been attended by a very high mortality, support the opinion held by many surgeons that a foreign body, unless so easily accessible along a short track that its removal naturally forms a part of the "toilet" operation, should be left alone. Much depends on the size, character, and position of the foreign body.

OPERATIVE TECHNIQUE.

If the circumstances are such as to permit of efficient treatment within, say, 24 hours of the infliction of the wound, that is to say, when a thorough examination can be made, when the patient's condition warrants operation, and when the means are available for the carrying out of a well planned surgical technique, early operation promises good results. The following points as to the line of treatment may be indicated briefly:

(1) *Anæsthesia.*—In the hands of those accustomed to its employment and familiar with the technique, local anæsthesia with novocain and adrenalin has proved of value, and presents definite advantages. The head can conveniently be elevated, and the patient may even be operated upon whilst in the sitting posture. thus diminishing intracranial tension; hæmorrhage from the scalp is reduced to a minimum; the patient can be made to assist the operator in raising the intracranial pressure by coughing if required to do so, and post-operating vomiting is abolished. A preliminary dose of morphia or "omnopon" helps the patient to submit to the ordeal. Restless, fractious, and timid patients are best operated upon under general anæsthesia, when gas and oxygen may serve for a well morphinised patient, or ether may be administered by Shipway's apparatus. Chloroform should be avoided.

(2) *Cleansing the scalp.*—The whole scalp should be shaved and thoroughly cleansed.

(3) *Excision of wound.*—The wound should be excised, the greatest care being taken to avoid soiling of the resulting wound, by employ-

ing clean instruments, towels, &c., for the further stages of the operation.

(4) *Incision.*—The best incision to expose the damaged brain is a subject of difference of opinion. Some prefer always to enlarge the original wound, and to work through that; others feel that the turning down of a flap gives the best exposure. Whichever may be used, the essential point is to secure adequate access to the damaged bone.

(5) *Removal of bone.*—Less damage is done to the brain by working through a trephine hole made at a little distance from the fracture than by attempting to use the original opening as a starting point. An area of bone should be removed large enough to expose at least half an inch of normal dura around the wound in that membrane.

(6) *The treatment of the dura mater.*—The dural opening, if obviously ragged and dirty, may be trimmed, but too much caution cannot be exercised in judging when and to what extent this should be done, and too much gentleness cannot be used in carrying out this step; a cortical vessel may be wounded, giving rise to troublesome bleeding, and, in the attempts to arrest this, further damage may occur, or the sub-arachnoid space may be opened and infected.

(7) *Treatment of brain.*—Through the dural opening the damaged brain must be treated with the greatest possible gentleness. A piece of metal, and bony fragments lying close to the surface, may be removed with forceps, the finger gently feeling for them. As each fragment is carefully pulled out, disintegrated brain and small blood clots emerge, and, if the operation is conducted under a stream of hot (115° F.) normal saline, this is washed away at the same time that hæmorrhage is checked, and the necessity for swabbing is avoided. The depth to which the finger may be inserted must be gauged by the direction of the track in relation to the position of the ventricle, for it is of the utmost importance not to risk opening into it. Usually, the intracranial pressure falls with the removal of fragments and débris, but, if the tension is so high as to embarrass the manipulations owing to the bulging of the brain into the opening, a lumbar puncture may be done.

Another method of dealing with the cerebral track is to avoid digital exploration by using a soft rubber catheter. The catheter is gently introduced into the track, and the débris removed by suction *with a ball syringe.* The electromagnet has been used from time to *time for the extraction* of shell fragments.

(8) *Closure of wound.*—The operation is completed by closure of the scalp wound. The actual method must depend upon the size and shape of the excised wound, and whether or not a flap has been made. One method is to employ the usual incisions of plastic surgery for sliding of flaps to close the defect completely. This has the advantage of covering the cranial wound with skin, and, when the healing takes place by first intention, the results are excellent. In certain cases the defect in the scalp caused by excision of the original wound can advantageously be closed by a plastic operation, which depends upon the sliding of pericranial flaps across the gap. Details of these methods and their modifications have been published.

Procedure at a later stage.—In cases operated upon early and with good technique, it is of the greatest importance to make as complete a closure as possible. When for any reason the operation cannot be done until sepsis has obtained a firm hold, the line of treatment indicated above must be modified in certain respects. By this time the sub-arachnoid space should have been shut off by adhesions between pia arachnoid and dura mater round the opening, and the track into the brain may be grossly infected. Here a similar operation may be carried out, but drainage has to be provided. For this purpose a tube or roll of rubber may be made to lead from the dural opening (without entering the brain track), beneath the scalp, and out through a part of the incision remote from the sutured or otherwise closed original wound. The continued high intracranial pressure due to the encephalitis is liable to cause the brain to crowd into the opening and so block drainage from the track. If this occurs the sceptic softening extends deeply, and ultimately reaches the ventricle.

The after-dressings are of the utmost importance, great gentleness and scrupulous cleanliness being necessary. Some use Dakin's solution by Carrel's method, others an oily preparation of dichloramine T. Glycerine has been used largely and with success.

Lumbar puncture is useful in relieving pressure either during the concussion stage or later. It is a safe proceeding when the dura mater is intact, but considerable caution is necessary when this membrane is lacerated. In the latter event, the withdrawal of fluid may, owing to the sudden reduction of pressure, allow the brain to fall away from the surface, thus breaking down the adhesions between the pia arachnoid and the dura mater, and exposing the meninges to infection.

When, therefore, lumbar puncture is done in the presence of a wounded dura mater, whether for diagnostic purposes or for relief of pressure, only a small quantity of cerebro-spinal fluid, *e. g.*, 2–6 drachms, should be removed at a time. The puncture may be, however, repeated frequently if necessary.

Evacuation of men with head injuries.—When a case has been submitted to operation, the patient should be kept as quiet as possible for at least a fortnight before being moved.

Favourable cases should not be transferred from the base to England for at least three weeks after operation.

Section XII.—SPINAL INJURIES.

Nature of bone lesions.—The spinal cord may be injured directly by the missile, or by in-driven fragments of the vertebral column which lacerate it or compress it, or indirectly by the concussion effect of a projectile, generally of high velocity, which touches the vertebral column. The latter condition, which is quite common, is found when the bullet has either passed through the body of the vertebra or touches the spinous articular or especially the transverse process, and often occurs without any extensive fracture of the vertebræ.

Nature of medullary lesions.—The medullary changes vary; in many cases there are small scattered hæmorrhages, especially in the grey matter; occasionally a single large hæmorrhage; but more frequently œdematous swelling of the whole cord with considerable disintegration of its tissues and central softenings are found; extensive extra-dural hæmorrhage is very rare.

Symptoms of spinal injury.—The symptoms produced by these three types of injury are very similar and depend on the site and severity of the lesion. It is very difficult to determine the degree of the injury or the prospect of recovery in the earlier stages, as the loss of power is almost invariably complete at first, and, as the knee jerks are often absent for some days in even slight cases, this fact cannot be regarded as a sign of complete transverse lesion. The state of tone in the muscles of the lower limbs and the reflex movements that can be obtained from the soles are the only reliable indications.

Within the first two weeks stimulation of the soles generally gives no reflex response in the severest cases; in less severe injuries there may be isolated flexion of the great toes, or this movement associated with contraction of the hamstrings, while in more favourable cases a withdrawal reflex of the limb, with extension of the great toes and often dorsiflexion of the foot (Babinski's sign), is obtained. Account must be taken of the level of the injury, as lesions of the lumbo-sacral cord and cauda equina more readily abolish these reflex move-

ments and the tone of the muscles than injuries at a higher level. The early return of the knee and ankle jerks is a favourable sign.

Diagnosis from functional paraplegia.—As the symptoms of organic paraplegia may be easily confused with those of functional or hysterical paralysis, which is not infrequently observed, especially in men who have been buried in broken-in trenches or under sandbags, attention may be drawn to a few points in their differential diagnosis. In hysterical or functional paraplegia sphincter control is not affected, while retention of urine is invariably present in severe organic lesions. In the latter condition the limbs are always flaccid at first, while they are often rigid, or the tone of the muscles is increased, and the knee and ankle jerks are usually exaggerated, in hysterical palsy. Absence of these reflexes, on the other hand, is invariably evidence of organic injury. Babinski's sign, when present, is also, of course, evidence of organic disturbance. Further, in hysterical states there may be no sensory disturbance, or, if there be any loss, it may take the form of stocking or glove anæsthesia, or occupy a distribution not explicable by any single organic lesion.

Treatment of spinal injuries.—The treatment of the spinal injuries of warfare is extremely disappointing. Operation is successful in only very rare cases, and should be undertaken only when X-ray examination shows a missile lying against the spinal cord, or when its passage has driven in fragments of bone on to the cord. Even in these cases the results of operative interference have not been promising. The danger of infection spreading to the meninges through a laceration in the dura mater, which had been closed by a piece of depressed bone or by a clot, must be considered. In the concussion cases, in which the cord is not injured directly by the missile or by fractured bone, operation can do no good. There can be no doubt, however, that a certain proportion of the cases tend to recover and will regain useful power, but improvement must necessarily be very slow.

Treatment of complications.—The main object of treatment must be the prevention of the complications which threaten life. Many cases of spinal injury die from associated wounds of the chest or abdomen, but the fatal termination in a large proportion of the others is due to cystitis and septic pyelonephritis. The greatest care is consequently necessary in the passage of the catheter, and urinary antiseptics should be administered to all patients from as *early a stage as is* practicable. Frequent irrigation of the bladder is

equally important, both as a preventive measure and as a mode of treatment if infection has started. A solution of quinine sulphate, 1 to 2 grains to the ounce, has proved very satisfactory for this purpose.

The merits of suprapubic drainage are still undecided. An operation which permits leakage round the tube is to be avoided, especially when the patient has afterwards to be transported from hospital to hospital. It is impossible in such circumstances to keep the patient dry, so that the risks of bedsores are greatly increased. There are methods, however, of overcoming this difficulty, and when such operations can be done they present advantages over the ordinary methods of catheterisation and irrigation.

Suprapubic drainage.—One such method which has proved satisfactory is as follows: A 2-inch median suprapubic incision is made and the full bladder exposed. With an ordinary sinus forceps or Spencer-Wells forceps, held closed, a stab is made through the bladder wall, and then the blades are separated just widely enough to permit the introduction of a Guyon self-retaining suprapubic tube, stretched on a long probe. When the forceps is removed, and the probe is withdrawn, the tube is found to be tightly gripped by the bladder wall, and the junction to be completely watertight. The tube should be pulled out until its expanded end lies against the anterior wall of the bladder. By a glass connection and a long rubber tube the urine can be conducted to a vessel hung to the side of the bed.

After this operation, irrigation should be carried out daily with some suitable fluid, such as permanganate solution, in the following manner:—The nozzle of a Higginson's syringe is introduced into the urinary meatus and held there with one hand, whilst with the other the fluid is pumped through the urethra into the bladder and out through the suprapubic tube. If the tube becomes blocked it can usually be cleared by syringing through it into the bladder. A new tube needs to be used about every week or ten days, as the rubber perishes easily, allowing the tube to become kinked and so blocked, when leakage is liable to occur.

Transportation of cases of paraplegia.—Cases of paraplegia should be sent to the base hospital at once, if possible, on account of the need for suitable beds and water cushions, and because they require special care in nursing. The bladder should always be emptied when the patient arrives at the clearing station and before he leaves it.

All serious cases should be transferred to England as soon as possible, but as the spinal injury may be aggravated in the course of the transit, patients with slighter and recoverable lesions should be kept as quiet as possible at the base for two or three weeks. This especially holds good for those cases in whom the vertebral column is fractured, or when in-driven fragments compress the cord; and more particularly still for cases of concussion in the cervical region, in which there is some evidence to show that secondary degenerative changes are liable to develop.

LESIONS OF THE PERIPHERAL NERVES.

Injuries of nerves are very liable to be overlooked, because they do not give rise to obvious symptoms complained of by the patient, and in many cases they are overshadowed by more serious wounds. For these reasons it is all the more necessary that surgeons should be on the watch for nerve injuries, and examine patients for symptoms before they are anæsthetised, for it is very desirable that whenever nerves are found to be divided they should be carefully sutured whenever this is possible. Even if the suture should not hold permanently, the temporary fixation of the divided ends will effectually prevent their retraction, and will also maintain them in the same plane, so that a subsequent operation for secondary suture will be greatly facilitated.

Section XIII.—WOUNDS OF THE CHEST.

WOUNDS OF THE CHEST AT THE FRONT.

Wounds of the chest form about 2 per cent. of all wounds. A through-and-through bullet wound is the most, a shell wound less, favourable. If the diaphragm is perforated, the prognosis is graver. If the spinal cord is injured, it is very grave. Fragments have been successfully removed from the pericardium and heart wall, and in at least one case a patient has been sent to the base, apparently well, with a fragment in the wall of the left ventricle.

The mortality of uncomplicated wounds of the pleura and lung varies under different circumstances. Delayed collection, bad weather, long transport, and rough roads increase it. In casualty clearing stations where uncomplicated chest wounds have been distinguished from those with abdominal and spinal injury in addition, the mortality has varied from 7 to 19 per cent. Of those cases which reach the base about 6 per cent. die of sepsis. Of those which reach England practically none die. Retention of a small foreign body in the lung or pleura does not appear to retard recovery.

At A. D. S.—Treatment.—At the advanced dressing station, patients with severe shock should be rested in the most comfortable position, usually the semi-recumbent, restored as far as possible by heat and hot drinks or rectal injections, and given morphia, but not more than half a grain. This greatly lessens the respiratory distress.

Closure of open wounds.—Open wounds into the pleura through which air is drawn in inspiration, or blood leaks, should be closed. This must be so done as to prevent air being sucked in as well as being blown out, otherwise a positive pressure in the pleura may result (valve pneumo-thorax). Closure may be done—

(1) By insertion of deep stitches through the skin without an anæsthetic.

(2) By plugging the hole with gauze, firmly covered with strapping.

Evacuation.—The patients should be evacuated to a casualty clearing station as soon as they are fit to travel.

At casualty clearing stations.—Of those who die in the casualty clearing station, about half die in the first 24 hours. They succumb to injuries so severe that surgery is unavailing. By far the most frequent cause of the remaining deaths is septic infection of the pleural cavity. The object of the surgeon, therefore, is to remove all sources of infection, and at the same time to restore the normal function of the lung.

Methods by which pleural cavity is infected.—The pleural cavity may become infected in various ways:

(1) The missile and portions of clothing and splinters of rib carried by it into the pleura or lung may form centres of infection.

(2) A wound opening directly into the pleural cavity and through which air is sucked will always lead to infection and often to the death of the patient unless closed.

(3) The wound in the chest wall is, like all other wounds, infected, and, especially when the muscles are badly lacerated, may become the seat of septic processes which extend into the pleura.

Treatment on arrival.—On arrival, the patient should be put to bed and, if symptoms of shock are present, no attempt should be made to remove the clothing until there is some recovery.

Examination of patient.—A survey should then be made of the whole body, and all wounds examined. It should be remembered that injury to the contents of the chest may be caused by missiles entering another part of the body, such as the face, the neck, the shoulder and even the pelvis. Evidence of hæmothorax, pneumothorax, collapse of lung, or displacement of the heart, should be sought for. Much may be gained by careful examination of the movements of the chest as a whole. The body should be searched for complicating wounds, especially with regard to abdominal and spinal injury. Cases in which the missile has not passed out of the body should be examined by X-rays, by which valuable information may be gained concerning:

(1) The position and size of the foreign body.

(2) The existence and extent of hæmothorax and pneumothorax.

(3) The condition of the opposite lung, cardiac displacement and movements of the diaphragm.

THE QUESTION OF PRIMARY OPERATION.

1. *Cases which do not require primary operation.*—These form the great majority of all the cases. They include—
   (1) Small clean wounds, including through-and-through bullet wounds, without evidence of serious intrathoracic injury other than hæmothorax.
   (2) Cases in which a missile is retained which is only of small size.
   (3) Cases in which a retained missile, though of large size, is in a position which is difficult of access.
   (4) Cases of uninfected hæmothorax. It is not justifiable to open the pleura in such cases within the first day or two merely for the sake of evacuating the blood.
2. *Cases in which primary operation is indicated.*—
   (1) A ragged wound of the soft parts.
   (2) Compound fracture of ribs.
   (3) Bleeding from the parietal wound and intercostal artery.
   (4) Pain (often the result of in-driven splinters of rib scratching the pleura with each respiratory movement).

   For the above cases, as a rule, there is no need to explore the pleural cavity.
   (5) An open wound of the thorax through which air is pumped in and out of the pleural cavity.
   (6) Retention of a large foreign body in an accessible position.

   For these cases the larger operation must be performed. They do not form more than from 10 to 15 per cent. of all cases.
3. *Cases in which primary operation is contra-indicated.*
   (1) Shock and collapse, such as would be contra-indications for any surgical procedure.
   (2) Collapse of the opposite lung, as indicated by inspiratory retraction of the chest wall. In this condition the administration of an anæsthetic and the opening of the chest may be fatal. Such a condition may result, among other causes, from a plug of blood and mucus being sucked into the bronchus of the unwounded lung.

TREATMENT BY OPERATION.

An operation for removal of a foreign body from the chest should never be undertaken without careful localisation.

Operate early if at all.—If an operation is to be done, it should be undertaken as soon as possible after the initial shock has passed off, and before sepsis has become established. After the lapse of 48 hours it is rarely advisable to perform any operation, except for evacuation of an infected pleural cavity.

Operations.—It is found by experience that operation can usually be undertaken about six hours after admission to a clearing station.

Clean soft parts.—If nothing else be done, wounds of the soft parts, unless small and clean, *e. g.*, rifle bullet wounds, should be excised, because otherwise they will suppurate, and infection may spread along the track of the missile into the pleural cavity, giving rise to empyema.

Remove splinters.—Excision of the wound of the soft parts should be extended down to the ribs, which are frequently broken. Whether or no further operation is undertaken for opening the chest, the splinters of bone should be removed, jagged ends of rib cut cleanly off and all dead tissue excised.

Examination of the wound in this way may reveal, either a bleeding intercostal artery, or a large hole leading into the chest, and a finger introduced into the pleural cavity may discover splinters of bone free or sticking into the lung. These should be removed, as they play a large part in the production and maintenance of infection.

Close the chest.—At this stage the case has been converted into one of open thorax: if it is decided not to open the chest further, the blood should be evacuated by rolling the patient on to the side, and then the thorax should be closed in layers—pleura to pleura, muscle to muscle, and skin to skin.

When there is a deficiency of pleura, muscle should be brought over the gap; when there is a deficiency of pleura and muscle, skin should be brought over the gap even if a flap has to be cut. The chest *must* be closed.

Retention of large foreign bodies.—By this is meant a shell fragment about 1 inch by ½ inch, with which are associated as a rule splinters of in-driven rib and clothing. Much more importance must be attributed to the damage caused by the missile and the organisms carried in by it than to retention of the foreign body itself. But if

the missile lies free in the pleural cavity, or projects into it either from the lung or chest wall, it should be removed.

When it is decided that the removal of a retained foreign body is necessary, the operation may be undertaken either through the wound or by fresh thoracotomy.

Route for removal.—The choice of route depends upon the position of the foreign body relative to the wound of entry. Where possible, thoracotomy through the wound is preferred, because in any case the wound of the parietes has to be excised and less damage is done to the chest wall by a single resection.

Thoracotomy through the wound.—If the route chosen is through the wound the procedure will be that detailed above for excision of a wound, but instead of the removal of the broken ends only, a resection of rib 4 inches in length will be necessary.

Thoracotomy by fresh incision.—This may be done by resection of 4 inches of rib, by splitting rib, or by incision of an intercostal space.

The easiest route is *via* the fifth rib in the mid or anterior axillary line, whence, with the insertion of a retractor or rib spreader, any part of the pleural cavity can be reached. With the chest thus widely opened, the damaged lung can be seen and the foreign body may be visible; if blood obscures the view it should be removed by rolling the patient, syphoning or mopping. If not visible the foreign body may be sought by inserting the hand into pleural cavity, and may be removed through the wound of entry into the lung, or by fresh incision into lung tissue.

Treatment of wounded lung.—Early operation, even within 12 hours of the receipt of the wound, does not usually cause recrudescence of bleeding. Bleeding stops when the lung collapses, and it only continues in those rare cases, usually as the result of adhesions, in which the lung is unable to collapse. Lung tissue may be incised without fear; any fresh bleeding is easily controlled by suture.

When readily accessible the wound of the lung should be cleansed either by excision or by wiping with gauze, and all fragments of bone and cloth removed. The hole in the lung should always be closed by suture, because, if left open, organisms can pass from the lung to the pleural cavity, where they will give rise to empyema. The lung is capable of dealing satisfactorily with a very considerable amount of infection enclosed within its own tissues.

Manipulation of the pleural contents can be done freely without dangerous fall of blood pressure.

Cleansing the pleural cavity.—In most cases it is only necessary to swab the cavity clean and dry. If, however, there has been much soiling, it is advisable to wash it out with either warm saline or some non-poisonous antiseptic. In any case the chest should be left dry, as this is an essential factor in the early expansion of the lung.

Closure of the chest.—Whether the operation has been performed through the wound or by fresh incision, the chest should always be closed. The relief afforded to the patient is instant and marked.

Blood transfusion.—Many lives have been saved by blood transfusion after the operation is completed.

Post-operative treatment.—Watch should be kept, by puncture with an exploring needle, for accumulation of effusion in the pleural cavity. If bacteria are shown to be present, and increasing in numbers, and the patient has the clinical symptoms of infection (*see* pp. 108, 109), then stitches may be removed and a tube inserted through the wound into the pleural cavity.

Another treatment that has been employed with great success in these cases is repeated aspiration without re-opening of the wound. In one casualty clearing station where this method was carried out, it was possible to keep the patients a long time. On the second or third day after the operation, aspiration was performed as a routine measure, and all fluid drawn off. This frequently showed infection. But, nevertheless, no free opening was made. Aspiration was repeated as often as seemed necessary, sometimes on six or seven occasions, with the result that the temperature eventually fell, the lung expanded, the fluid ceased to collect, and after being up and about for some time the patient was evacuated. It must be remembered that owing to the pneumothorax that follows the operation, physical signs of fluid are usually misleading. Other symptoms, and especially the temperature, were the guides to aspiration. A considerable series was successfully so treated.

Anæsthetics.—These patients bear operation well, and take a general anæsthetic satisfactorily, provided that there is no damage or collapse of the opposite lung. Local anæsthesia may be employed for the chest wall, but if an intra-thoracic operation is to be performed, a general anæsthetic should be administered. Gas and oxygen is probably the best anæsthetic to use; if not available, chloroform may be given with oxygen through a Shipway apparatus. Ether *is* contra-indicated.

Where there is no need for immediate operation, it is wise not to disturb the patient more than is absolutely necessary on the first day, and to be content with examining the front of the chest alone. On the following day, when the patient has recovered from the effects of the journey from the front, the examination may be completed.

Heart.—The most important point of all is the *position of the heart.* In most cases the apex can be felt, or the cardiac dulness determined. But in some patients weakness of the beat prevents the first, and traumatic pneumothorax the second. Auscultation will then usually enable us to say whether the heart is much displaced, but sometimes even the sounds are inaudible. The determination should be made as accurate as possible, since the situation of the heart is not only on indication of present conditions in the chest, but any subsequent change in its position is of great importance in the early diagnosis of sepsis.

Lungs.—The movements of the chest on the two sides, the vocal vibrations, the percussion note over the front and axilla, and the respiratory and vocal sounds, should next be noted, Nearly always the wounded lung expands less, and breathes more weakly than the other. But vocal vibrations are not by any means always diminished over a hæmothorax. Sometimes they are even increased. If dulness, which, on the wounded side, may be always taken to imply hæmothorax, reaches the mid-axillary line, the effusion may be reckoned large enough to need aspiration within a day or two.

Both sides must be equally examined, for many missiles pass across the chest, and may produce the greatest injury on the side opposite to the wound of entry.

In bad weather many have bronchitis before they are wounded; it is a serious complication.

Abdomen.—The abdomen should be examined, and any pain, tenderness, or rigidity noted and watched for evidence of abdominal injury.

Surgical emphysema.—Subcutaneous emphysema is not infrequent, and is usually quite harmless even when extreme. It might almost be said to be favourable to the prognosis. But it renders examination very uncertain. Percussion is useless, and the crackling of the air in the tissues simulates râles. By firmly pressing the stethoscope on to the chest these noises can often be stopped, and the breath sounds heard.

Pneumothorax.—Early pneumothorax due to the injury of the lung passes off in a day or two as a rule, but occasionally it increases and causes complete collapse of the lung with great distress. It is then very dangerous and requires free opening of the chest. The signs are full or excessive expansion of the side, boxy resonance over the whole or a large part, absence of breath-sounds, displacement of the heart to the opposite side, a rapid pulse and great distress in breathing. If there is any doubt X-ray examination will settle it.

The great majority of patients who have not needed early operation recover steadily and uninterruptedly. At the end of three days from the date of the wound the temperature and pulse rate tend to fall, and the breathing becomes quiet. The patients can then be evacuated safely.

Complications.—Patients who are distressed at the end of three days are not fit to travel, and the cause of their distress must be ascertained. It may be found on the wounded, or on the opposite unwounded side.

1. *The wounded side.*—(i) *A large hæmothorax*, reaching as far forward as the mid-axillary line, is by itself sufficient to produce dyspnœa even when uninfected. A large hæmothorax should be drawn off by aspiration as completely as possible on the second or third day.

Aspiration.—The aspiration should be done slowly, taking fully half-an-hour, and with only moderate suction. When so treated the pleural cavity does not refill.

Open operation.—There are some cases, not common, in which though there is evidently a large effusion very little can be drawn off by aspiration even though the needle is inserted in more than one spot. Further attempts at aspiration should be made on subsequent days with the help of X-rays. If these are still unsuccessful the case should be treated by resection with closure of the wound. A large effusion cannot be left unevacuated, and a large clotted effusion, which these sometimes are, may lead to a very dangerous sepsis.

(ii) *By far the commonest cause of distress is septic infection, and this is in every case the presumption unless definite reasons can be found against it.* After the first 24 hours, the chief task of the medical officer is to be on the watch for the symptoms which indicate it.

Symptoms.—The patient looks unwell, is restless, and sleeps badly.

*The face is so*metimes pallid, sometimes unhealthily flushed.

The tongue is sometimes, but by no means always, dry, and the appetite is bad.

The temperature usually rises and the pulse and respiration become more rapid.

Septic pneumothorax.—In many septic cases gas forms in the effusion, and produces pneumothorax, which displaces the heart. It is not sufficiently realised that, as a rule by the third day, traumatic pneumothorax has disappeared and any pneumothorax which then exists is due to sepsis. Beside the usual signs over the collection of gas, the heart will be decidedly displaced from its first position. Pneumothorax displaces it readily but hæmothorax surprisingly little. The only causes of further displacement of the heart toward the unwounded side after admission are septic hæmothorax by formation of gas or inflammatory effusion, and collapse of the unwounded lung.

Jaundice, pleural friction on the opposite side and pericardial friction are usually indications of sepsis. Pericarditis may, however, be evidence of injury to the pericardium itself.

Exploration will often reveal a stinking fluid.

When this is found the diagnosis is certain, but in any case in which sepsis is suspected it is advisable to rely rather on clinical than on bacteriological evidence. For on the one hand it is not infrequent for the exploring syringe to draw off a sample which is sterile, though septic infection has taken place in another part, and on the other infections differ much in danger. The mere presence of a few organisms is not enough ground for resection.

Treatment.—Resection should always be performed in cases where the effusion is foul, or the clinical symptoms point to severe infection. Where neither of these conditions was present, many patients whose effusions were the seat of infection by organisms of low virulence have been successfully treated by the far less serious method of aspiration. The aspiration should be repeated when necessary. Streptococci if numerous, and especially if hæmolytic, are the most dangerous. A mixed infection is commonly severe.

2. *The unwounded side.*—(i) *Pneumonia.*—It is not uncommon for pneumonia, probably due to inhalation of septic material from the wounded side, to arise in the opposite lung. It gives the usual signs with high fever and quick pulse and respiration.

(ii) *Congestion ? hypostatic.*—In some cases the opposite lung becomes deeply congested without any wound, and without any

probability of contusion by the missile. These cases become dyspnœic and cyanotic. Over the congested area, which is usually the lower lobe and the posterior part of the upper lobe, there are loud râles, and sometimes local bronchial breathing.

(iii) *Collapse.*—In a certain number of cases, collapse takes place in the unwounded lung. The lower lobe is the part usually affected. That part of the chest is retracted and motionless. It gives the ordinary signs of solid lung, dulness and either weak or bronchial breathing, but no fever. The heart is drawn to the collapsed side, and the dome of the diaphragm can be seen by the X-rays to be much elevated. Patients are not as a rule cyanotic unless they sit up. Often an unexpected dyspnœa or cyanosis on moving the patient is the first indication of the condition. Collapse is not dangerous so long as the patient is kept quiet, and passes off in a week or less.

Medical treatment.—The medical treatment of chest wounds is simple. As a rule the patients like being propped up, and Fowler's position is the easiest. When they slip down the head is often pushed forward on to the sternum by the pillows, which is very uncomfortable for the patient, but seldom noticed by the attendant. This can be obviated by the use of special "Fowler frames" placed on the bedstead.

There is nearly always severe distress in breathing after the journey down. It can be relieved by morphia (1/4 grain) or heroin hydrochloride (1/20 grain), which will be required on admission, and frequently again at night. It is very important that the patient should sleep, and if one injection is not sufficient, a second should be given in a few hours. Owing, however, to the fact that many soldiers possess morphia, some patients come down already overdosed, and the medical officer should be on the watch.

If there is cough and expectoration, a sedative expectorant such as equal parts of Tr. Camp. Co., Tr. or Oxymel. of Squill, and Syrup of Tolu, or a draught made with Tr. of Squill, Spirit of Chloroform, and if there is spasmodic dyspnœa a few minims of Liquor Morphinæ Acetatis, is useful. If there is a difficulty in expectoration a stimulant expectorant with 3—4 grains each of carbonate of ammonia and iodide of potassium is better. For the prevention of septic broncho-pneumonia, it has been suggested to give 2 minims of *creosote* in mucilage three times daily from the time of admission.

Date of evacuation from C. C. S.—As already stated, patients with a small hæmothorax who are not distressed may be safely evacuated 72 hours after the injury. A patient with a large hæmothorax should wait for a day after aspiration and, if then comfortable, may be sent down.

Patients with pneumonia, bronchitis, hæmorrhagic congestion or collapse of the unwounded lung, should not travel till recovery from these conditions has taken place.

Patients who have had severe operations should be retained for 10 days at least.

CHEST WOUNDS AT THE BASE HOSPITALS.

Patients with wounds of the chest do not usually reach the lines of communication hospitals before the fourth day after the infliction of the wound. Under exceptional circumstances such cases may be received as early as the second day. In a certain number of cases, more especially when operations involving the pleural cavity of the lung have been performed at casualty clearing stations, they do not arrive until from one to two weeks after the date of wounding.

Non-penetrating wounds of the chest, *i.e.* wounds of the chest wall and so called contour wounds, may give rise to both pleural and pulmonary injuries and complications. Pleurisy, either dry or with effusion, and empyema are not uncommon complications of such wounds and are frequently due to extension of inflammation from the wound to the pleura, or they occur in association with the more or less extensive injuries to the ribs that are often present in contour wounds. Bruising of the lung and hæmorrhagic infiltration of the lung to a greater or less extent are the most common injuries of the lung directly following these non-penetrating wounds. In rare instances a hæmothorax may result without any actual wound of the pleura and it is probably due to the rupture of the visceral pleura over an area of hæmorrhagic infiltration of the lung. Pneumonia of a broncho-pneumonic type is a not infrequent complication of non-penetrating wounds of the chest wall. The lung is involved on the same side as, and in the vicinity of, the chest wall injury. The bruised lung infiltrated with blood is prone to become infected either from the lung itself or more usually by the

spread of infection from the wound track in the chest wall, and thus a broncho-pneumonia or lobular pneumonia of septic type is developed. The frequency of broncho-pneumonia in gunshot injuries of the chest wall alone is in marked contrast to the rarity of such inflammatory complications of the lung in cases of penetrating wounds of the chest producing hæmothorax where the lung is compressed or collapsed beneath the fluid effused into the pleural cavity but is not pneumonic. The presence of hæmothorax and also the layer of fibrinous clot deposited in such cases on the visceral pleura seem to be a great hindrance to the spread of infective processes from the chest wall to the lung. Massive collapse of the lung, involving either the lower lobe or in some instances the entire lung, is an occasional complication of these non-penetrating wounds of the chest wall, but it is remarkable that the most marked type of this condition, *i.e.* that involving the whole of one lung, is most usually seen on the side of the chest opposite to that injured. In these cases of massive collapse involving the whole of one lung and of the contralateral type the gunshot wound of the chest wall is often almost trivial in character and very seldom is of sufficient severity to cause anxiety.

Hæmoptysis may occur in cases of non-penetrating wounds, and is presumably due to hæmorrhagic infiltration of the lung. It may occur very soon after the infliction of the wound but more usually some delay takes place and the symptom is not present until some hours or even days after the wound. Occasionally it is not only protracted in duration but also severe in amount. The occurrence of hæmoptysis is not, therefore, absolute proof that the chest wound is a penetrating one.

Complications are apt to develop in cases of non-penetrating chest wounds where infection of the pleura or lung has occurred. Thus, where broncho-pneumonia, pleural effusion, or empyema is present, contralateral pleurisy or pneumonia may develop, and pericarditis is not rarely seen in such cases. Severe bronchitis of a purulent type may also supervene.

The treatment of non-penetrating wounds of the chest is usually simple. The most important points are to recognise early the existence of pleural effusion and also the frequency with which such effusions are infected. Hence the necessity for exploratory puncture to determine this point and for promptness in treating any empyema *by the usual methods.*

Penetrating wounds of the chest usually produce one or more of the following conditions, subcutaneous emphysema, hæmoptysis, hæmothorax, pneumothorax, and laceration of lung. Bilateral effects, however, may often be seen as the result of unilateral wounds and injuries, since they may be due to such complications of unilateral hæmothorax as contralateral pneumonia or contralateral massive collapse. It is sometimes difficult when bilateral physical signs are present to differentiate between bilateral injuries and a unilateral injury with a complication on the uninjured side.

Subcutaneous emphysema has been mentioned on p. 107.

Hæmoptysis is very general in penetrating chest wounds. It occurs either immediately or very soon after the wounding, and the patient often states that his mouth fills with blood. By the time the patient reaches a base hospital, the hæmoptysis is not generally at all profuse, but it may be accompanied by a trying and painful cough. It usually subsides within 10 days or a fortnight from the date of the wound. Hæmoptysis is not a symptom of great moment and death from hæmoptysis at a base hospital is exceedingly rare. It has occurred in a very few instances as a result of secondary hæmorrhage associated with laceration of the lung or the presence of inflammatory lesions around a retained missile in the lung. Hæmoptysis may be due to bruising of the lung with hæmorrhagic infiltration and infarction, together with inflammatory reaction in the track of the wound in the lung. In these cases the sputum is sticky, viscid, and bloody, and the patient may go on expectorating such material for a week or more. Such hæmoptysis may be delayed in its onset and not occur until the lapse of many days after the wound.

Hæmothorax is the most common result of a penetrating chest wound. Pneumothorax and pneumohæmothorax are both relatively rare. The blood effused into the pleural cavity is derived in the great majority of cases from the wound in the lung. In some cases it may come from injured vessels in the chest wall, but this is exceptional. In rare instances its source is an injury to very large vessels, even the thoracic aorta, and such cases may live for many days. In the ordinary type of case the hæmorrhage ceases early, *i.e.*, before the third day, and does not recur except in very rare cases and then probably always in association with infection. Thus, in a series of 100 fatal cases of hæmothorax, secondary hæmorrhage into the pleural cavity occurred in only two cases, and in both infection was present.

The bloody fluid present in the chest in cases of hæmothorax consists in the main of defibrinated blood, *i.e.*, a mixture of serum and corpuscles, often presenting to the eye a strong resemblance to ordinary blood. The parietal and visceral pleura are covered to a greater or less extent with a layer of fibrinous clot, $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness, in the area corresponding to the hæmothorax. In cases where infection is present, the thickness of this layer may be much increased. The fibrinous clot on the visceral pleura is of considerable importance, since its presence materially hinders the re-expansion of the lung after the removal or absorption of the fluid.

In addition to blood, the hæmothorax fluid contains a pleural exudate, even in cases of sterile hæmothorax. This is shown by two facts. First, the cell content of hæmothorax fluid is different from that of defibrinated blood in that an increased number of lymphocytes may be present, together with endothelial cells, eosinophile cells, sometimes in large numbers, and marrow cells. Secondly, the quantity of fluid present in the chest, even in sterile cases, may be very large, *i.e.*, four or five pints, and yet the patient may not show signs of any excessive anæmia. Further evidence of the presence of a pleural exudate is afforded in some cases by the occurrence of a peculiar clotting in the fluid removed from the chest by paracentesis. This clotting resembles that seen in the fluid of ordinary pleural effusions in its gelatinous character, but differs from it in that the clot may contain red corpuscles. It is explained by supposing that the pleural exudate has added coagulable material to the defibrinated blood present in the pleural cavity, and that red corpuscles have become entangled in this secondary clotting to a greater or less degree. In a certain number of cases of sterile hæmothorax, defibrination of the extravasated blood either does not occur, or occurs only to some limited extent, or in some abnormal manner. In the first case, a massive clot may be formed and occupy the pleural cavity, so that little or no fluid can be removed by aspiration. In the others, a finely shredded clot may be formed, and in yet others a viscous fluid is found that is withdrawn with great difficulty by paracentesis.

In cases of infected hæmothorax, the pleural exudate is much more abundant, and is often poured out rapidly, so that the amount of fluid in the chest may increase considerably in amount in the course of 24 or 48 hours. Polymorphonuclear leucocytes are found in abundance in the fluid, whilst it may yield a deposit of pus visible to the naked eye. Further, the fluid itself is often of a deep crimson

colour owing to the extensive hæmolysis that has occurred. Although marked hæmolysis is a valuable criterion of the presence of infection, slight hæmolysis may be found in hæmothorax fluids where there is no bacteriological evidence of the presence of organisms. Massive and extensive clotting is also much more common in these infected cases, and large clots, possibly softening and with naked eye evidence of infection, may be found in the lower portions of the pleural cavity, between the diaphragm and the chest wall, and also in the vertebral groove. In a considerable proportion of the cases there is not only an abundant pleural exudate, but in addition there is gas formation, owing to the infection being associated with the presence of anaërobic gas-producing organisms. The formation of gas is often very rapid, and causes the development of a general or of a localized pneumothorax in addition to the hæmothorax already present. Such cases often present a very definite and typical clinical picture.

Condition of lung.—The more important points in the morbid anatomy of hæmothorax are the following. The degree of collapse of the lung, and more especially of the lower lobe, is very considerable, and often seems to be greater in amount than that seen in ordinary pleural effusions of similar volume. In other words, the collapse is often not in direct relation to the amount of fluid present. The overdistension or so-called emphysema of the upper portion of the lung above the fluid is certainly far greater than that seen in cases of pleural effusion. The anterior surface of the over-distended upper lobe is frequently pressed up against the chest wall, and the anterior margin of the lung extends well beyond the middle line of the chest. This explains the frequent presence of Skodaic resonance extending beyond the middle line, and so simulating to some degree the clinical picture of pneumothorax. There may be a few loose fibrinous adhesions glueing the surface of the lung to the chest wall at the upper limit of the effused blood. The parietal pleura, in the area corresponding to that of the effused blood, is coated with a layer of fibrinous clot, and the surface of the collapsed lung is similarly coated to a greater or less extent. The collapsed lung beneath the hæmothorax rarely if ever presents any signs of inflammatory mischief or consolidation, except in the immediate vicinity of the wound track and around any retained foreign body. It seems immune both to pneumonia and to purulent bronchitis. In infected hæmothorax the deposit on the surface of the lung and parietes is

much more abundant, and thick layers of more or less organized lymph may be present, together with clots. In many cases these clots may be breaking down, and contain small collections of pus or gas together with shreds of clothing, fragments of the missile, or other foreign bodies. Bilateral hæmothorax may be present, and the collections of fluid are usually small or moderate in size. They may be either sterile or infected. Cases have occurred of bilateral infected hæmothorax that have recovered after drainage of both pleural cavities. In other instances a sterile hæmothorax has been present on one side with infected hæmothorax on the other.

Infection.—The proportion of infected cases to sterile varies considerably from time to time, but in a consecutive series of 450 cases infection was proved to be present in 25 per cent. The infection may be either early or late. In the former it manifests itself within the first few days or even hours after the wound. In the latter, the case presents at first the signs and symptoms of a sterile hæmothorax, and then in the second or even the third week after the wound the clinical picture of infection develops. In some instances of delayed infection, the development of serious symptoms is very rapid, and such cases are apt to be erroneously diagnosed as due to secondary hæmorrhage or to increasing pneumothorax, when in reality they are due to a rapidly developing infection. In an appreciable number of cases, the patient's general condition, and more especially the temperature chart, may suggest the presence of infection, but bacteriological examination fails to reveal the presence of organisms in the hæmothorax fluid even though repeated examinations are made at intervals of several days, and then suddenly a further examination shows the presence of numerous organisms. It is probable that in these cases the infection was at first more or less localized by blood or recent adhesions, and then with the spread of the infection, the general mass of hæmothorax fluid has suddenly and after a variable delay become infected. In approximately 80 per cent. of the cases of infected hæmothorax, streptococci, staphylococci or anaërobic bacilli are present. In the remaining 20 per cent., pneumococci, bacilli of influenza, or *Micrococcus tetragenus* are found. In approximately 50 per cent. of the infected cases anaërobic bacilli are present, either alone or in association with cocci. In most cases, therefore, the infection is evidently derived from the exterior, since the organisms found belong mainly to the groups found in the skin or to those present in fæces and soil, and it is carried in either by the missile or,

more often, by fragments of clothes or other contaminated material. The organisms normally liable to be present in the lung are only found in a minority of cases. In some cases the infection reaches the pleural cavity by direct extension from the wound track in the parietes.

Complications.—Purulent bronchitis, pleurisy, pneumonia, massive collapse of the lung and pericarditis, are the most frequent complications of hæmothorax, and all, except massive collapse, are more especially seen in association with infected hæmothorax. Pleurisy and pericarditis sometimes occur in cases where there is no bacteriological proof of the presence of infection in the hæmothorax fluid. Meningitis may occur as a very rare complication of infected hæmothorax, but no case of cerebral abscess has as yet fallen under the observation of the writer. Severe nephritis with œdema and uræmia is occasionally present in cases of infected hæmothorax that run a protracted course. Abscess and gangrene of the lung are rare complications, more often associated with the coincident lung lesions produced by the missile than with the hæmothorax as such. An intense jaundice of a deep orange hue is an occasional complication of severe cases of infected hæmothorax, especially in cases of anaërobic infection. Epistaxis, albuminuria, and some degree of purpura, may be present in these cases, and they are usually rapidly fatal, but recovery has taken place in some instances of intense jaundice where there has been no delay in surgical intervention. Jaundice more moderate in degree may occur in other infections, more especially in those due to streptococci. Purulent bronchitis affecting the opposite lung is a common and often a serious complication. Congestion and œdema of the opposite lung is also common in infected cases. Contralateral pneumonia may occur, but care must be taken in the differential diagnosis of this from contralateral massive collapse, and this is often difficult.

Massive collapse.—Massive collapse is a common complication of which two varieties are seen. In one form a relatively small unilateral hæmothorax is present, and with it there is massive collapse, involving the whole lung on the same side as the hæmothorax. In the second variety the massive collapse is contralateral, and involves either a portion or the whole of the lower lobe of the lung on the unwounded side. Massive collapse of the contralateral type, but involving the entire lung, is seen in non-penetrating gunshot wounds of the chest that have produced no lesion of the pleura or lung on

the side wounded. Contralateral pleurisy is not uncommon in hæmothorax. It is usually dry, but an effusion may collect, especially in cases of streptococcal infection, and an empyema may develop.

Pericarditis is a serious complication also most frequently seen in streptococcal infections, but in some instances it has occurred with anaërobic infections of the hæmothorax, when the pericardium has been injured by the missile. In such cases the pericardium contains not only an effusion but also gas, and two cases at least have recovered after opening and draining the pericardium. In rare instances, where a right-sided hæmothorax occurs in association with a wound of the liver, bile has been poured out in large amount into the chest. Such cases may run a sterile course and recover after repeated paracentesis and the removal of large quantities of bile. Jaundice does not necessarily occur in such cases.

Signs and symptoms of hæmothorax.—The symptoms depend mainly on the presence or absence of infection and complications. In a simple uncomplicated sterile hæmothorax the symptoms are not urgent after the first two or three days, unless the hæmothorax is very large in amount, *i. e.* more than 3 pints. Dyspnœa, although at first urgent, is not usually a marked feature after the third day. It is, however, much increased by exertion and movement, hence many patients on arrival at a base hospital after a long journey have considerable dyspnœa and distress for 24 hours. Moderate pyrexia is usually present, and the temperature may, for a short time, rise to 103° F., but it is more usually about 100° F. The pulse is not much accelerated, and is usually well under 100, and, although the respirations are moderately quickened, and often shallow, the patient is not conscious of this, and has but little distress unless cough is present. This may be frequent, painful, and ineffectual. The state of the wound may cause coughing to be acutely painful.

The continued presence of pain, distress, high fever, rapid pulse, and furred tongue, should always suggest the probability of the hæmothorax being infected, and a sample of the fluid should be removed with an exploring syringe without delay, in order to determine this point by bacteriological methods. If the result is negative, and the symptoms persist and no other cause for the pyrexia can be found, such as the presence of complications or the state of the wound or wounds, the exploration should be repeated, and, if necessary, several *punctures at different* levels should be made, as the infection may

be a localised one. Tenderness, on slight pressure, over some portion of the chest wall is very suggestive of infected hæmothorax, provided it is not due to surgical emphysema or to fractured ribs. Rapid pulse and dyspnœa are both valuable signs of infection, and jaundice, if severe, is practically certain evidence. In wounds of the right lower chest in such a position as to suggest the possibility of the liver being wounded, the significance of jaundice as a sign of infected hæmothorax is liable to be overlooked. It is attributed to hepatic injury when in fact no such lesion is present and the jaundice is solely due to the existence of an infected hæmothorax. Hiccough is suggestive either of toxæmia or of a wound of the diaphragm. Occasionally very severe and persistent hiccough is seen where neither of these conditions is present, but the patient is neurotic. The symptom then seems to be of functional origin.

The *physical signs* present with hæmothorax are very characteristic, and are by no means necessarily the same as those usually regarded as typical of pleural effusion. In cases of very large sterile hæmothorax, and in cases of infected hæmothorax, where there has been a considerable pleural exudate, the signs often resemble more or less closely the usual physical signs associated with pleural effusion. In the great majority of cases of hæmothorax, however, the signs are very different, and are as follows: The affected side is immobile and often retracted, in which case the retraction may be either very marked and general, or else and more usually, it is local and especially marked in the lower costal region. The diaphragm on the affected side is abnormally high and also immobile. This high position of the diaphragm is readily demonstrated by percussion in cases of left-sided hæmothorax, owing to the greatly increased area of stomach resonance. It is also one of the most characteristic features on X-ray examination. In some instances this tympanitic stomach resonance may reach so high a level as either to merge into the area of infraclavicular Skodaic resonance, or to be separated from it by only a narrow band of dulness. A mistaken diagnosis of pneumothorax may readily be made by want of care in examing and in interpreting this high stomach resonance.

The Skodaic resonance in the uppermost intercostal spaces is much more marked, and is obtained over a more extensive area than is usual in pleural effusions, and, as already mentioned, it not infrequently extends beyond the middle line, and thus again is liable to be confounded with the resonance of a pneumothorax. The dis-

tinction, however, is easy, since, in cases of Skodaic resonance, the vocal fremitus is increased and the breath sounds are harsh. Over the area of the fluid the percussion note will be dull, but, on auscultation, it is by no means uncommon for the breath sounds to be tubular, and for bronchophony, ægophony, and even pectoriloquy, to be extremely well marked. All these signs may be present over a large area, and in some cases the tubular breathing is amphoric in character. Even in cases where the retraction of the affected side is well marked, the heart may be displaced to a considerable degree towards the opposite and unwounded side.

Evidence of infection.—In some cases of infected hæmothorax, where there is a rapid increase in the pleural exudate, the physical signs change rapidly. Thus, on one day the physical signs just described may be present, *i. e.*, immobility, retraction, and tubular breathing, but 24 hours later the affected side is bulged, and weak or absent breath sounds are present instead of loud tubular breathing. Exploratory puncture in the first stage may have demonstrated the presence of fluid, with but few organisms, whereas in the second stage, with the increased exudate, massive infection may be found. In other cases, there is not only a rapid increase in the amount of the pleural exudate, but, in addition, there is gas formation, leading to the production of either a localised, or, in some cases, to a more or less generalised pneumothorax. In cases where the gas is localised, a most characteristic sign is the replacement of the dulness previously present by an extremely well marked cracked-pot percussion note. This note is usually elicited best in the axilla and lower chest. Such cases often present also a sudden and great increase in the degree of the cardiac displacement. These signs are of great practical importance, inasmuch as they are very significant of infection being present, even if the patient does not at the moment show marked signs of illness. They are especially liable to occur in cases of delayed or late infection, and their presence calls for immediate surgical treatment by resection of a rib, washing out the pleura, and drainage.

In an ordinary hæmothorax of moderate size, the physical signs present more analogy to those usually regarded as typical of pneumonic consolidation than to those attributed to fluid, yet morbid anatomy shows only fluid with collapsed lung beneath it. When massive collapse is present on the wounded side, and involves the *whole lung, in association* with a small or moderate hæmothorax,

the signs are also very typical. In such cases the side is retracted and immobile, and, on percussion, dulness may be elicited over the whole side as high as the clavicle, the breath sounds may be weak, absent, or tubular, and the heart is either not displaced or else is displaced towards the affected side. The position of the heart gives the clue to the correct interpretation of the signs, and further evidence is yielded by the rapid changes that take place on the re-expansion of the affected lung. Further confirmation may be afforded by X-ray examination at short intervals.

Contralateral collapse.—Massive collapse of the contralateral type also presents a very typical clinical picture, especially when it occurs as a complication of a non-penetrating gunshot wound of the chest, and involves the entire lung. It may occur within 24 hours of the wound, but in some cases the condition develops only after the lapse of several days. In such a case the side is retracted and immobile, the heart is greatly displaced towards the affected side and away from the wounded side, and often the displacement is not only lateral, but also upward. Dulness will be elicited on percussion, and the breath sounds may be weak, absent, tubular, or amphoric, with well marked bronchophony and pectoriloquy. The diaphragm will also be displaced upwards and be immobile. In cases of hæmothorax, contralateral massive collapse is also often present, but in these cases only the lower lobe, or a portion of the lower lobe, is apt to be involved, and hence the physical signs are less obvious. Another characteristic feature of massive collapse is the fact that the physical signs change rapidly: thus the weak or absent breath sounds may be replaced by loud tubular breathing, and the heart may return towards or to its normal position, without any operative treatment of the hæmothorax by paracentesis. These changes occur rapidly, sometimes in 24 or 48 hours, periods far too short for any appreciable absorption of the exudate to have occurred. In cases of massive collapse involving the entire lung, three weeks or a month may elapse before the heart has returned to its normal position, and, even when this has taken place, some physical signs, such as tubular breathing, with bronchophony, may still persist over an area in the vicinity of the angle of the scapula. During the stage of re-expansion of the lung, abundant fine crepitant râles may be heard over the area of lung involved; such signs are apt to be attributed to pneumonia. During this stage an abundant viscid or mucoid expectoration may be present, but it is important to recog-

nise that, in some of the most marked instances of massive collapse, *i. e.*, those involving the whole of one lung, there is no expectoration throughout the course of the case.

Signs and symptoms of pneumothorax or pneumohæmothorax.—Pneumohæmothorax.—In pneumohæmothorax the clinical picture is very similar to that of hæmothorax, but the dyspnœa may be rather more marked, and the physical signs are somewhat different. The displacement of the heart may be greater, and the percussion note elicited above the level of the fluid is very resonant, and the breath sounds in this area are weak or absent. The coin or bell sound is present in many but not in all cases. In some this characteristic sign is not elicited over the chest in the infraclavicular region, but is obtained at a lower level, *e.g.*, at the level of the third or fourth rib, and in an antero-posterior diameter directed towards the axilla.

It is probable that in these cases the air is, as it were, pent up, above the fluid of the hæmothorax and below the upper lobe of the lung, the latter being still in contact with the chest wall anteriorly. In some instances where the percussion note at the apex and the weakness of the breath sounds have suggested the presence of pneumothorax, but the bell sound was absent, *post-mortem* observations have shown that extreme emphysema of the upper lobe and not pneumothorax was present. In pneumohæmothorax the level of the line of fluid dulness changes materially when the patient is moved from the recumbent or semi-recumbent position to a sitting posture, and on X-ray examination the level of the fluid is horizontal and changes readily with slight changes of posture.

Pneumothorax.—Several varieties of pneumothorax occur. In some little or no fluid is present as a complication, in others, especially when infection is present, very large amounts of fluid, *e.g.*, 7 pints, may be present. The great majority of cases of traumatic pneumothorax recover rapidly. There are, also, other cases where a complete or general pneumothorax is present with complete collapse of the lung, but with relatively little displacement of the heart. In such cases there may be no marked bulging or overdistension of the affected side, and some respiratory movement, more especially elevatory, may be present. In some of these cases the patient presents such slight symptoms that the chest lesion may be overlooked, more especially if the wound of entry is on the opposite

side of the body to that of the pneumothorax, or in some distant part such as the neck or face.

The most important variety of pneumothorax is that in which the condition is really due to the formation of gas as the result of anaërobic infection of a hæmothorax, and where the apparent pneumothorax develops under observation. In these cases urgent symptoms, such as dyspnœa, tachycardia, pallor, sweating, and intense distress may develop rapidly in the course of 24 hours, when, previously to their onset, no symptoms causing alarm were present. In such cases great displacement of the heart takes place, sometimes in a few hours, so that it may be said that the rapid development of an apparent pneumothorax, or the rapid increase of an existing pneumothorax, occurring some days after the wound, is in itself strong evidence of the presence of infection, and should call for immediate exploratory puncture. If infection be found, surgical measures should be taken at once to open, wash out, and drain the infected pleural cavity. Limited pneumothorax arising from localised collections of gas in the lower portions of the pleural cavity are generally due to infection, but a small number of cases where air was apparently present, and no evidence of infection could be found, have occurred. Such collections are due to the presence of adhesions in the pleural cavity.

Diagnosis.—The fact that contralateral complications are often present in cases of unilateral injuries renders the problem a difficult one. The degree of impairment of the respiratory movements of the chest and the position of the heart are most valuable points. In all cases the position of the cardiac impulse should be searched for and determined if possible. Lateral displacement of the heart towards one side may be due to massive collapse of the lung on that side or to pleural lesions, hæmothorax or pneumothorax on the opposite side, or to both. An increase in the displacement is usually an indication that infection is present in a hæmothorax. A decrease may be due to the disappearance of massive collapse, or to some absorption of the pleural contents (fluid or air), or to redistribution of the pleural exudate owing to increasing compression of the lung by the fluid. The degree of displacement of the heart in any given case is therefore an uncertain guide to the size of a hæmothorax.

The main problem in diagnosis is the determination whether infection is or is not present, and the most difficult cases are

those where the case runs an apparently sterile course, no other symptoms being present besides a pyrexia that is persistent. Microscopic and bacteriological examination of the fluid withdrawn by paracentesis will generally determine the presence or absence of infection, provided that care be taken to repeat the exploration and too much stress is not laid upon a negative result obtained at the first puncture. Care must be taken in considering the diagnostic significance of persistent pyrexia to see that it does not arise from some local condition in the wound, or some complication, such as purulent bronchitis. Contralateral pleurisy and pneumonia and pericarditis are complications that suggest the presence of infection. The extreme rarity of pulmonary inflammations in the compressed lung on the side of the hæmothorax should always suggest, in the presence of urgent symptoms, that infection of the fluid is present rather than pneumonic consolidation, although the physical signs present may closely resemble those of consolidation. In all such cases an exploratory puncture should be made without delay, since it is essential for the successful treatment of infected hæmothorax that the diagnosis of infection should be made as early as possible.

Treatment in lines of communication hospital.—In sterile hæmothorax of small amount there is no need for any active treatment, as such cases do well, although their progress is sometimes slow. If the effusion is large in amount, so that the percussion dulness reaches well above the angle of the scapula, the fluid should be removed by paracentesis about the sixth or seventh day after the wound. In a few cases earlier aspiration may be necessary in order to relieve distress arising from the amount of the fluid present in the pleura.

Aspiration.—Aspiration with oxygen replacement is preferable to simple aspiration, for two reasons; firstly, the operation can be carried out without discomfort to the patient provided local anæsthesia is used, and secondly, all the fluid present in the chest can be removed at one sitting. It is rarely possible to do this with ordinary aspiration, as the development of symptoms of varying intensity, such as a sense of constriction of the chest, cough, or distress, compel the cessation of the aspiration long before all the fluid has been withdrawn. These unpleasant symptoms develop as a consequence of the sudden change in the intra-pleural pressure resulting from the removal of fluid, and if oxygen replacement be used they do not occur. In all aspirations the fluid should be drawn off slowly. In *infected hæmothorax*, the chest must be opened by the resection of a

rib and the pleural cavity emptied of its infected contents. In some cases, especially of the milder forms of infections, the chest can be closed again immediately after thorough cleansing of the pleural cavity with Dakin's solution or eusol. In others, especially where the infection is more severe, drainage is necessary, but even where drainage is employed, many cases can be successfully closed after a short interval, *e. g.*, one to three weeks, provided that the infected cavity be treated by washing out with an antiseptic such as Dakin's solution, or be treated by the Carrel-Dakin method.

Drainage of pleura.—In cases where an infected hæmothorax has been washed out and the chest closed an effusion often recurs. In many cases this can be successfully treated by aspiration, repeated several times if necessary, but in a certain proportion of cases drainage is required. Care must be taken in selecting the site for excising a portion of rib in order to provide drainage, and the fact that the diaphragm is abnormally high in hæmothorax must be borne in mind, as otherwise the opening will be made too low down. In cases of sterile pneumothorax, aspiration may afford relief, but where infection is present, the cases must be treated by resection of ribs and in the same manner as an infected hæmothorax.

Evacuation to England.—Cases of gunshot wound of the chest, where there has been a pleural or pulmonary lesion, should not be evacuated until the lapse of three weeks from the date of the wound.

Section XIV.—WOUNDS OF THE ABDOMEN.

At the beginning of the war neither the military situation nor the equipment of the medical service permitted of the successful performance of large numbers of abdominal operations at the front. Before many months, however, the fixed line of trenches permitted of the establishment and equipment of the casualty clearing stations in such a way as to provide the opportunity for all operations that might be required.

It soon became evident that the great majority of those who were wounded in the intestines died, and it also became clear from *post-mortem* examinations both that the injuries inflicted by either bullets or shells were so extensive that repair and recovery could not be expected without operation, and also that very many patients died from hæmorrhage, which might have been arrested by the surgeon. The result was that the treatment of gastrointestinal injuries by rest, opium and abstinence from food was abandoned, and operation became the rule.

THE NATURE OF THE INJURIES IN ABDOMINAL WOUNDS.

(1) If a missile traverse the area occupied by the hollow viscera it must be assumed that these have been wounded. It is possible for a missile to pass across the intestinal area without opening the bowel, but such an occurrence is quite unusual. This has happened with shrapnel bullets more often than with fragments of shell or rifle bullets.

(2) In some injuries of the abdominal wall, and especially when caused by large fragments of shells or bombs, the intestine may be severely injured, or even torn completely across, without the peritoneal cavity being opened.

(3) The small intestine is seldom wounded in one place alone; there are generally many wounds, and both the large and small intestines are often injured by the same missile.

The mesentery is often injured, and it bleeds more profusely than the intestine. It is sometimes torn away from the bowel for several inches, so that a loop of gut subsequently becomes gangrenous as a result of arrest of its blood supply. This does not occur if not more than about an inch of mesentery is torn.

(4) The liver is frequently wounded without other viscera being hurt, and fragments of shell are often left buried in its substance. If the kidney or spleen are injured the colon is often injured also.

(5) Abdominal wounds are often complicated by wounds of the lung and sometimes by injury to the spinal cord. When the diaphragm is torn, hernia of the omentum and large intestine into the pleura is frequently seen.

(6) The site of entry of a missile is frequently at a distance from the abdominal wall, *e. g.*, in the shoulder, the chest or the buttock. The entry wound may be extremely minute, for the very smallest fragments of metal may be driven through the abdominal wall into the intestine and may leave a wound of the skin so small that it looks like a superficial abrasion and is very liable to be overlooked. If the entry wound is through the buttock there is often a very dangerous compound fracture of the pelvic bones in addition, and these wounds are especially liable to be affected by gas gangrene.

The intraperitoneal injury caused by missiles passing through the buttock is often very extensive, and may involve the rectum, the bladder, and the small intestine. Buttock wounds penetrating the abdominal cavity are therefore very frequently fatal in spite of operations.

(7) Hæmorrhage is the cause of nearly all deaths which occur within 12 hours of the wound, but it is also true that if a patient has lost much blood, and yet does not die of bleeding, he is very liable to die from the shock of an operation or else from a sepsis which he has not the vitality to resist. The patients who have lost very little blood show a much higher rate of recovery than those who have bled profusely, even though they may have severe intestinal injuries.

(8) Peritonitis does not occur early in wounds of the small intestine or of the stomach unless the latter is full of food, which escapes. The contents of the small intestine often do not escape for six or eight hours after the injury. The contents of the large intestine escape quickly; they are much more septic, and cause a more early

and severe peritonitis. They are also very liable to set up a dangerous sepsis in the sub-peritoneal cellular tissue, which is often fatal.

(9) Gas gangrene is liable to occur in the retroperitoneal muscles and cellular tissue, especially if there is a hæmatoma.

DIAGNOSIS.

It has been found that many of the injuries of the solid viscera do very well without operation, and that the most important question to decide is whether the stomach or the intestines have been injured. In through-and-through penetrating wounds this question can generally be settled by anatomical knowledge, on the assumption that the hollow viscera are almost always wounded if the area of the abdomen containing them is traversed by a missile. All such cases require operation. When the missile has entered through the thorax or lumbar region, and is retained, the case is less clear, and the surgeon is much assisted by an X-ray examination, although he must rely mainly upon the symptoms exhibited by the patient, and this is especially the case when the entry wound is at a distance from the abdominal wall. Severe and diffuse abdominal pain and tenderness are almost always present if morphia has not been given, and they are more important signs of intestinal injury than any others. Rigidity of the abdominal wall is commonly found, but it is often quite as well marked in cases where the lung and the diaphragm have been wounded, and the abdomen is not injured at all. Vomiting is often absent in the early hours after an intestinal wound, and is often present when the hollow viscera are uninjured and there is only blood in the peritoneum; its presence or absence is therefore of little value.

The pulse is often quiet, but it generally rises quickly within a few hours of the injury. The facial expression is often very characteristic, and is rarely free from an appearance of anxiety or distress.

OPERATION.

If a diagnosis of probable injury to the gastro-intestinal tract is made, the custom in the British Army is to operate, and this is contra-indicated in those cases alone where the patient is either obviously dying or else where he is not brought to hospital until 36 hours or more have elapsed since the wound was received.

Time for operation.—It has been found that if so long a time as 36 hours has elapsed, the chances of recovery are better without operation, and there is no doubt that patients have occasionally recovered without operation after being wounded in the intestines. If operation is required, the sooner it is done the better, but in wounds of the small intestines or stomach the results of operation are good if not more than eight or nine hours have passed since the receipt of the injury. It is only after ten hours have passed that the mortality rapidly increases, and after a delay of 18 hours the percentage of recoveries becomes very small.

If the pulse is as much as 120 to the minute, the chances of recovery are slight.

If a patient is cold and collapsed on admission, it is generally right to put him to bed and rest him, and apply warmth for an hour before operation. The limbs and the chest should be kept well covered during the operation itself, and the operating theatre should be well warmed.

Anæsthetic.—The best anæsthetics are gas and oxygen and warmed ether vapour, and, if the patient is suffering from shock, the latter should be combined with oxygen. (*See* p. 42.)

The chances of recovery from an abdominal wound are much less in winter than in summer. This is partly due to the effects of cold and wet upon a patient who has lost much blood, and partly to the greater prevalence in winter of bronchial catarrh; for many patients die after operation from bronchitis and broncho-pneumonia.

The following rules are generally observed in operating on the stomach or intestines:

Rules for operation on hollow viscera.—(*a*) The operation should be performed as quickly as possible.

(*b*) The incision should therefore be sufficiently large to permit of easy examination of the viscera.

(*c*) A para-central incision is usually the best, but in lateral wounds a paracostal or lumbar incision may give better access to the flexures of the colon or to the kidneys or spleen.

(*d*) The intestines should be kept inside the abdomen as much as possible. They should be examined in their whole length before suture or resection is decided upon. Resection should never be done if it can be avoided, and it is better to suture many holes in the intestines than to resect the injured coils. Thin silk and linen thread are the best materials to use, and a single continuous suture which in-

verts the peritoneum is quite sufficient and secure. If resection is necessary, end-to-end joining is better and quicker than lateral apposition.

(*e*) Blood should be gently sponged out, and abdominal lavage should not be employed. The abdominal incision should be very carefully and firmly closed in its whole length. Drainage should not be employed, except that a tube may be placed in the pelvis for the first 24 or 36 hours if the peritoneum is much soiled.

(*f*) Injuries of the lumbar colon should generally be operated upon by a lumbar incision so as to avoid spreading infection over the peritoneum. The cellular tissue around the colon should always be drained. If much of the colon is injured colostomy should be performed at the site of the injury.

(*g*) Wounds of the rectum, if intraperitoneal, should be treated by suture. If they are extraperitoneal they always require free drainage and in some of them colostomy is necessary.

(*h*) Wounds of the bladder opening the peritoneum are generally complicated by injuries of the rectum or the small intestine. They should be sutured with catgut and the bladder should not be drained by a catheter.

Extraperitoneal wounds of the bladder may be sutured or drained according to the absence or presence of other injuries. Missiles in the bladder should always be removed.

(*i*) If the diaphragm is badly torn, it must be carefully sutured, for, if this is not done, few patients recover. (*See* p. 137.)

(*j*) If the patient has a wound in the back which requires that he should be turned on to his face in order that it may be opened and cleaned this should always be done before the abdomen is opened, as it causes much collapse to do this at the end of an abdominal operation.

(*k*) Intravenous injections are much more useful than subcutaneous infusion of fluid, and where much blood has been lost, *transfusion is often required at the end of the operation.*

THE SOLID VISCERA.

As injury to the solid viscera is chiefly dangerous on account of hæmorrhage there is generally no object in operating unless it is believed that bleeding is still progressing. This is comparatively rarely the case, so that operations on the spleen, kidney, and liver

are not usually to be undertaken in wounds of these organs. If operation is required on the kidney or the spleen the opening up of the wound and packing it with gauze will usually arrest hæmorrhage. If it does not, the torn part may in some cases be sutured, using by preference a round bodied blunt needle, but if the main vessels are torn or the organ smashed, excision is required. Secondary hæmorrhage from the kidney is not uncommon and is generally due to sepsis. In such cases nephrectomy is generally necessary.

Wounds of the liver.—Bleeding from the liver is difficult to arrest by operation, but in some few cases packing with gauze may be of use. If large fragments of shells or bombs are lodged in the liver they are likely to set up a very dangerous suppurative hepatitis and should be removed after they have been located by X-rays.

Most wounds of the liver do not require treatment by operation.

Wounds of the pancreas are generally complicated by other injuries and are commonly fatal.

POST-OPERATIVE TREATMENT.

After operation the patient should at first be kept lying down in bed and be warmed as much as possible. After 6 to 12 hours he may be propped up in a sitting position. Saline solution with a little brandy should be given frequently per rectum from the first. Distension of the bowels is usually treated by the intramuscular injection of pituitary extract and the administration of half an ounce of glycerine per rectum.

RESULTS.

The results of operations on the abdomen have improved, and this is no doubt due to the increased experience of the surgeons at the front.

It is not yet possible to give statistics for the whole British army but the following figures will show the results obtained in certain areas.

Statistics of the whole of the abdominal cases in a certain area during a period of two years show that, of 1,605 operations, 47.1 per cent. recovered.

The published statistics of two hospitals in another area, for a period *of active fighting, show* that out of 856 patients treated by operation,

416 recovered and 450 died, *i.e.* about 49 per cent. recovered. It is thus evident that it is quite possible, even in heavy fighting, to save the lives of many men, and it is satisfactory to observe that the recoveries during a battle may be as numerous in proportion as during quieter periods, a result which must be attributed to good and quick evacuation as much as to good surgery. Another series of cases may be quoted to show what results may be obtained "in quiet times." Total number of operations 111, of which 67 recovered and 44 died. A recovery rate of 60.4.

ABDOMINAL WOUNDS AT THE BASE.

HOLLOW VISCERA.

1. Those which have not been operated on at the casualty clearing stations or advanced abdominal hospitals: These cases are very rare now, but are occasionally seen. A few have been successfully treated by laparotomy. Certain upper abdominal wounds and colon injuries recover without operation.

2. Cases operated on at the front: In a large proportion of these no serious symptoms arise while the patients are at the base. The following complications, however, are sometimes seen:

(*a*) *Infection of the laparotomy wound.*—This may reveal itself as a limited infection, or the whole wound may break down. In a certain proportion the muscular and fascial layers gape, leaving the abdominal contents with a covering of peritoneum only. In rare cases the whole wound opens and intestine presents.

The treatment adopted at the base is to strive for clinical sterilization of the wound and to perform secondary suture.

(*b*) *Fæcal fistula*, especially in colon and rectum cases, is occasionally seen. In a fair proportion of these the fistula closes spontaneously. The other cases are dealt with on ordinary surgical principles, and, if possible, are transferred to England for further operative treatment.

(*c*) *Adhesions.*—As might be expected adhesions are sometimes met with after abdominal operations at the front. If intestinal obstruction is present, the abdomen is opened and the adhesions are dealt with as in civil practice.

(*d*) *Intra-abdominal abscess.*—Subphrenic abscess is occasionally seen. Abscesses also sometimes develop in the pelvis, and in the

general cavity of the abdomen. These are dealt with by laparotomy and drainage.

Wounds of the rectum.—Intraperitoneal wounds of the rectum rarely escape notice at the operating centres at the front. Extraperitoneal wounds with perirectal abscess or fæcal fistula are comparatively common. Abscesses are treated by thorough opening up of the wound and drainage. Those behind the rectum may be dealt with in suitable cases by removal of the coccyx as in operations for excision of the rectum in civil practice. Usually, however, the fistula persists, and fæces in greater or lesser quantity escape over the wound. If much soiling of the latter is present, a colostomy is performed, preferably of the transverse colon. A sufficient spur must be provided to prevent fæces from passing into the efferent loop.

Bladder.—Intraperitoneal wounds which have been treated at the front by laparotomy, removal of foreign bodies if present, and suture without drainage of the bladder are not uncommonly seen at the base. These cases as a rule give no further trouble. If cystitis occurs treatment by irrigation of the bladder is usually successful. In some instances when the surgeon has been doubtful of the efficiency of his suture of the intraperitoneal wound suprapubic cystostomy has been performed.

Extraperitoneal wounds are frequently seen at the base. Most of these have buttock wounds communicating with the bladder, but wounds of the anterior abdominal wall, the thigh, or the rectum reaching the bladder are also seen. Many of these have been treated by suprapubic cystostomy at the front. Every effort is made at the base to keep them clean and dry, and various suction appliances are used for the purpose.

Even with the most careful precautions, however, it is difficult to prevent urine from leaking through a fistula when the latter is present. Irrigation of the bladder and urethra is necessary in these cases to minimise infection.

A fair proportion of cases of extraperitoneal wounds of the bladder reach the base with urine flowing from a sinus in the buttock, side of pelvis, rectum, etc., and without a suprapubic cystotomy. Contrary to expectation, many of these have done well, and have not required further operation on the bladder itself. Careful attention to the wound, and the provision of suitable drainage to prevent accumulation or pocketing of pus or urine have been sufficient. Irrigation of the bladder, and, if necessary, of the urethra has been carried out.

If foreign bodies are discovered by X-ray or cystoscope, removal is effected by a suprapubic opening. The latter is closed when the condition of the bladder warrants such a procedure. If severe cystitis is found the bladder is drained suprapubically. When there is a concomitant injury to the rectum and much soiling of the wound is present, a transverse colostomy is performed. When the leakage of fæces is slight and the condition of the patient is good expectant treatment is carried out. The skin must be carefully protected by the application of sterilised vaseline or some other emollient.

WOUNDS OF THE URETHRA.

These may be conveniently considered here. Wounds of the fixed portion of the urethra are best treated by perineal section, all blood clot and débris being removed. Suture of the urethra round a catheter has not been successful. It is preferable to leave the wound open for drainage, the patient being allowed to micturate through it. Later, when sepsis has been controlled, a plastic operation will have more chance of success. When complete division has taken place, the most that ought to be done at this stage is to bring the distal and proximal portions of the roof together. The floor ought to be left open for the exit of urine, as the results of tying in a catheter have been unsatisfactory, owing to the development of urethritis and cystitis, with, in some cases, extension of the infection to the kidneys.

Wounds of the pendulous urethra are usually evacuated to England when they have cleaned up sufficiently. Plastic operations are rarely performed at the base.

SOLID ORGANS.

Liver.—Many patients with bullet wounds traversing the liver arrive at the base without any troublesome symptoms or physical signs indicative of the injury.

Shrapnel or shell wounds are not so satisfactory, and are sometimes followed by jaundice and signs of effusion of bile or a mixture of bile and blood into the peritoneal and pleural cavities.

If the effusion is infected, death from septic absorption or secondary hæmorrhage may occur. Again, the presence of a foreign body may give rise to a hepatic or subphrenic abscess. Operative

interference is indicated when a localised hepatic or intraperitoneal abscess forms. In these instances, if a foreign body is present, it may be discovered and removed when the abscess is opened. Biliary fistulæ, even when the bile traverses the pleura, often heal spontaneously.

Wounds of the kidney may need surgical interference at the base for the relief of urinary extravasation or secondary hæmorrhage. Urinary extravasation may occur when the pelvis of the kidney or the ureter is injured, and if sufficient exit is not allowed the urine may track along the course of the ureter to the iliac fossa or pelvis, or rarely into the tissues of the back. A suitable incision will free this imprisoned fluid, and it will not be necessary to interfere with the kidney itself, unless very severe damage to the pelvis or ureter precludes the possibility of spontaneous cure or a plastic operation.

Secondary hæmorrhage.—In a series of cases of wounds of the kidney seen at the base, secondary hæmorrhage took place in 22 per cent. (9 cases out of a total of 42). In 5 of these the accident occurred between the 10th and 15th day. In some of these the wound in the kidney and soft parts was small and apparently clean.

Treatment.—When severe hæmorrhage takes place operative measures are imperative. In small, clean wounds, under suitable conditions, the wound may be sterilised, and a wedge-shaped portion of the kidney, including the affected area, may be removed, and the parts brought together by catgut sutures. In most cases, however, nephrectomy will be necessary. Before any operation on the kidney is indertaken, steps should be taken, if possible, to ascertain the presence and efficiency of the opposite organ. If the patient is severely blanched, a preliminary blood transfusion will improve his chances of recovery.

Section XV.—ABDOMINO-THORACIC WOUNDS.

Wounds involving the cavities of both the thorax and the abdomen are probably quickly fatal in a large number of cases, and of the patients who live to arrive at a casualty clearing station, those with abdomino-thoracic injuries form about 9 per cent. of all the penetrating wounds of the thorax. In one series of 644 cases there were 55 abdomino-thoracic wounds.

Most of these wounds are limited to one or other side of the body. Only a few are central, because the position of the heart and the great vessels renders these structures liable to be fatally injured when the wounds are central. Only a small proportion of these injuries involve one side of the chest and the opposite side of the diaphragm.

Most of the abdomino-thoracic wounds therefore may be classified as right and left, and it is necessary to divide them because of the different viscera involved and the different conditions and complications met with.

Importance of wound of the diaphragm.—In all cases there is necessarily a penetrating wound of the diaphragm, and the size of this is a matter of much importance. When the missile is very small, or when a rifle bullet makes clean wounds of entry and exit, the wound may be of no great importance. But if the missile is large or if, although small, it has passed obliquely, the wound in the diaphragm may be very extensive. It then becomes of the greatest importance.

Even if there is no injury to abdominal viscera a large wound of the diaphragm is in itself very dangerous to life. It is dangerous at once because of the difficulty of respiration and because the blood from the wounded lung is not confined to the pleural cavity, and so does not cause the natural arrest of the bleeding by producing a condition of collapse and of cessation of movement in the injured lobe. It becomes more dangerous soon, because of the hernial protrusions of the abdominal viscera through the torn diaphragm into the pleural cavity, and this danger is much greater on the left side than on the right because on the right side the liver blocks the aperture, as a rule,

and so prevents any hernia. On the left side, however, the suction action of the thorax in respiration, aided by the pressure of the abdominal muscles, draws into the pleural cavity the omentum and the viscera. Of these the most common is the colon, and this, in turn, draws in the stomach as well as the spleen. The small intestine may follow, and thus the whole pleural cavity may be filled by the abdominal viscera. It appears probable that the hole in the diaphragm may be stretched and torn by the pressure of the herniating viscera, and thus what was originally only a small aperture may be greatly increased in size.

These hernial protrusions cause great discomfort to the patient, and vomiting and dyspnœa are of common occurrence. It is probable that few patients survive who have a wounded lung and a large diaphragmatic hernia, although such cases have not been unknown in this war.

Cases in which the lung is not injured.—The lung is not necessarily injured in an abdomino-thoracic wound, and if there is no dyspnœa and no evidence of a hæmothorax or of a pneumothorax it may generally be assumed that the lung has escaped, especially if the position of the wound is close to the reflexion of the pleura at the base of the lung.

Many of these cases may be treated as if the wound was purely abdominal, but in others, suture of the diaphragm is required.

WOUNDS OF THE LUNG, WITH WOUNDS OF THE SOLID ABDOMINAL VISCERA.

The solid viscera most commonly wounded are the liver and kidney on the right side, and the spleen and kidney on the left side. The liver is most often wounded by itself, and, more rarely, in association with the right kidney, but the spleen and the left kidney are more frequently injured together.

The extent of the injuries to the solid viscera varies greatly, and is often in direct proportion to the size of the missile. If the missile is large, the wound is the more likely to be followed by sepsis if left unremoved, and it is also likely to cause continuing hæmorrhage if it lies in the liver.

Of 113 patients under the care of various surgeons, 62 recovered. Of the total, the liver alone was injured 64 times, with 35 recoveries; *the liver and kidney 8 times*, with 4 recoveries; the spleen 18 times,

with 6 recoveries; the spleen and kidney 4 times, with 2 recoveries; the kidney alone 6 times, with 4 recoveries; the diaphragm alone 13 times, with 11 recoveries.

DIAGNOSIS OF ABDOMINAL INJURIES WHEN THE LUNG IS INJURED.

In many of these cases it is very difficult to know whether an abdominal viscus is or is not injured, because any injury to the lung, and especially in the diaphragmatic region, is liable to cause both abdominal pain and hardness and fixity of the abdominal wall. It should be specially noted that, when there is no injury inside the abdomen, this rigidity will greatly relax if the patient is placed in the sitting-up position for 20 minutes.

In all such cases where the missile is retained, examination by X-rays is of the greatest value, as it will often decide at once that the missile has not entered the peritoneal cavity.

TREATMENT WHERE SOLID VISCERA ARE INJURED.

(*a*) *On the right side.*—If the missile is small, and has certainly penetrated only the lung and the liver, and is not retained, operation is usually only required if the nature of the wound of the lung indicates it, and the decision in such a case must depend rather on the thoracic than on the abdominal injury. If the missile is large and is retained in the liver, an operation should be performed. It is generally best to open up the thorax first, and to extract the foreign body through the wound in the diaphragm; it may also be necessary to enlarge the wound for this purpose. The wound of the lung can then be dealt with, and the aperture in the diaphragm closed. In some cases it is impossible to extract the missile through the diaphragm, and a separate incision has to be made in the abdominal wall.

(*b*) *On the left side.*—Operation is usually required without delay for the treatment of abdomino-thoracic wounds, because of the great difficulty of breathing and the tendency to diaphragmatic hernia. It should only be omitted when the missile is of very small size.

Suture of the diaphragm.—In all cases the operation should be directed first to the closure of the diaphragmatic wound, and this

closure should always be made from the side of the pleura, and not from the side of the abdomen. The reasons for this are: first, it is generally much easier to suture the torn diaphragm from the pleural side, and it is often impossible to close it from the peritoneal aspect. In addition to this, the operation of closure from the abdominal side involves much more handling of the viscera, and often necessitates a prolonged operation; second, if an operation is required upon the abdomen, it is much better to do this after the diaphragm and the pleura are closed, because the patient is in a much better condition when this has been done, and his respiration is infinitely easier.

Method and extent of operation.—In all operations for abdominothoracic wounds, the opening of the thorax must be followed by the complete cleansing of the whole pleural cavity, and the removal, by careful sponging, of all blood and blood clot and of foreign bodies or fragments of bone from the pleural cavity, or from the lung itself. It is only after the completion of this that the diaphragm is sutured, and the pleural cavity closed either by suturing the torn pleura itself, or if that is impossible, by bringing together the muscles and the skin in separate layers. The most complete asepsis is necessary if success is to be obtained.

Injuries of spleen and kidney.—If the spleen is torn, it may often be found in the pleura, and may be dealt with there by extending the thoracic incision, and so avoiding the making of a fresh incision in the abdominal wall. Slight tears of the surface do not require excision of the organ. If the kidney is wounded, it must be dealt with by operation, according to the extent to which it is injured. In most cases, where a wound of the spleen or kidney is diagnosed, it is best to make a paracostal incision. This allows the examination of both these viscera, and also of the colon.

WOUNDS OF THE LUNG, WITH INJURY OF THE HOLLOW VISCERA.

These injuries are exceedingly fatal. The stomach, the colon, or the small intestine may be wounded. In some cases both the stomach and the colon are injured, and, in others, the colon and the small intestine. In many cases both solid and hollow viscera are wounded. *Only a few patients* with such injuries have recovered.

In 55 cases of abdomino-thoracic wounds, the stomach or the intestine was wounded in 13, and of these only 3 recovered. In another series, the hollow viscera were wounded five times, with one recovery.

In another series of 20 cases, also treated by operation, there were 8 recoveries.

These make a total of 38 cases, with 12 recoveries.

TREATMENT OF WOUNDS OF THE HOLLOW VISCERA.

Where an injury to a hollow viscus is suspected, it is necessary to operate for its suture. If there is no definite evidence of injury to the lung, then the operation should be limited to the abdomen. If the wound is on the left side, and if there is a definite injury to the lung and a hæmothorax such as would justify an operation on the chest, the first operation should be for the closure of the wounded diaphragm and for the complete aseptic toilet, suture, and closure of the pleural cavity.

In many cases the injured abdominal viscera may be reached by enlarging the wound of the diaphragm. The stomach and the colon can usually be reached in this way, and a separate incision in the abdominal wall obviated.

Anæsthesia.—The administration of any general anæsthetic to these patients is attended by material risks, and the safest method is anæsthetisation by nitrous oxide and oxygen, with local infiltration by novocaine and adrenalin.

Blood transfusion.—In many patients the transfusion of a pint or more of blood after the operation is completed has apparently saved life, and it is a method of treatment which should be employed in a large number of those patients whose abdomino-thoracic wounds have been treated by operation.

Section XVI.—INJURIES TO THE EYES.

General considerations.—In dealing with injuries to the eye, the two questions which have constantly to be decided are:

(1) Will the eye be a useful organ of vision;

(2) Will it be a menace to its fellow by causing sympathetic ophthalmia.

Sympathetic ophthalmia.—Although a large number of ophthalmic injuries met with in warfare are so severe that the damaged eye is blind and has to be removed to prevent the risk of sympathetic ophthalmia in its fellow, yet there are many cases in which a useful eye can be safely retained by prompt and careful treatment. Not all the eyes which are blind need be removed, whereas many wounded eyes which have vision may lead, if incorrectly treated, to complete blindness of both. When one eye only is injured, in our endeavour to save it we must not forget that our main object is to keep the other sound, and to run no risk of sympathetic ophthalmia; on the other hand, when both eyes are damaged one must give each the best possible chance, in the hope that one at least may respond to treatment.

Before answering the above fundamental questions a complete examination of the eye must be made. This will take time and will require special apparatus. Till these are available, all one can do is to render first aid.

Immediate treatment.—The lids and parts around the eye should be cleansed and the conjunctival sac washed out with sterilised boric acid or saline solution to remove discharge or any loose foreign matter, and some sterilised 1 per cent. atropin ointment inserted between the lids. If no such ointment be at hand ophthalmic atropine tablets can be used, though these cause more irritation, are more difficult to manipulate, and are by no means always sterile by the time they get into the eye. The eye is covered with a sterilised pad and bandaged, till a complete examination can be made. Castor oil should not be used if there is a penetrating wound of the eye.

Examination of injured eyes.—In proceeding to a thorough examination, it should be borne in mind (1) that penetrating injuries, especially if associated with prolapse of uvea or lens capsule, are those most liable to cause sympathetic ophthalmia and thus lead to blindness in the other eye; and (2) penetrating injuries in military practice are very frequently associated with the embedding of foreign bodies in the eye, the skilled and early removal of which by means of electromagnets may lead to the saving of a seeing eye.

It is of the utmost importance therefore to decide at the earliest possible date, whether or not penetration has occurred. A penetrating wound may be so inconspicuous that the possibility of a small foreign body having been driven into the eye is easily overlooked. If there is penetration, or if it is thought probable or even possible, the sooner the eye is brought up to the large magnet the better, followed by an immediate and thorough treatment of the wound. Hence the importance of the following examination.

1. *General inspection.*—Look for wounds in the parts around, *e. g.* the lids, temple, brow or cheek, which may indicate the entrance of a foreign body that has passed into the globe.

2. *Proptosis* may be due to panophthalmitis or to a foreign body in the orbit having caused hæmorrhage or cellulitis. In the absence of damage to the walls of the orbit and panophthalmitis, proptosis associated with an anterior penetration of the eye indicates that a foreign body has passed right through the eye into the orbital tissues.

3. *Cornea.*—Search for foreign bodies or wounds, with or without prolapse or entanglement of the iris or lens capsule.

4. *Sclera.*—Look for foreign bodies, wounds or rupture, with or without prolapse of ciliary body or choroid.

5. *Anterior chamber.*—Note any hyphæma, hypopyon, or foreign body.

6. *Iris.*—Note whether the pupil is circular or irregular; its reaction to light; rupture of sphincter; tearing away from periphery (iridodialysis), or if there is a hole due to a foreign body having penetrated. Discoloration or muddiness indicates iritis or panophthalmitis.

7. *Tension.*—A very soft eye following immediately after an injury usually points to a wound or rupture; but this is not diagnostic, for an eye which is merely badly bruised may have a much reduced tension, and a ruptured eye may at times have a normal tension.

8. *Vision.*—This should be tested and recorded. If very defective, the field of vision should be taken roughly with the hand, and the projection of light tried.

9. Dilate the pupil when necessary and examine:

(*a*) *The red reflex*, and see if it can be obtained in all or only in some directions.

(*b*) *Lens*, for dislocation, cataract, or track of a foreign body.

(*c*) *Vitreous*, for hæmorrhage or foreign body. A yellow reflex usually indicates panophthalmitis.

(*d*) *Fundus*, for signs of concussion (hæmorrhage in the retina, or gross white patches, etc.); rupture of choroid, detachment of retina, or foreign body.

10. An *X-ray photograph* may be of great value (*see* below).

Having finished the examination, it must be decided (*a*) what is a useful eye, and (*b*) what eye is a menace.

(*a*) If there is perception of light and good projection, there is a possibility of a serviceable eye. Concussion of the retina and hæmorrhage into the vitreous lower the acuity greatly, but these changes may clear up and a surprising amount of vision return.

(*b*) An eye is dangerous, *i.e.*, liable to cause sympathetic ophthalmia, if there is a rupture or a penetrating wound of the globe, and especially when complicated with a prolapse of iris, ciliary body, choroid or lens capsule.

Sympathetic ophthalmia does not occur earlier than 10 days after injury, and rarely before three weeks, so that we may take 10 to 14 days to be the conventional period of safety in which to decide the fate of an eye. It is, however, a golden rule to form a definite opinion as soon as possible to avoid risk, and to remove the eye as soon as it is condemned.

Sympathetic ophthalmia never follows a non-penetrating injury. All merely bruised eyes can therefore be left with safety.

Whereas suppurating eyes (panophthalmitis) very rarely give rise to sympathetic ophthalmia, chronic inflammation of the iris or ciliary body (plastic iridocyclitis) as a result of penetrating injury, and particularly that form associated with keratitis punctata, is the condition par excellence which is the precursor of sympathetic inflammation and blindness.

A foreign body in the globe may lead to complete disorganisation of the eye through inflammation, but, in spite of traditional teaching,

practice shows that unless penetration by a foreign body is accompanied by prolapse of the uvea or lens capsule, it rarely, if ever, causes sympathetic ophthalmia.

Ruptured eyes.—When one eye only is ruptured and blind, it should be removed without delay, certainly within the first 10 days after injury; however badly disorganised, the remains should not be left (*see* Excision).

When both eyes are ruptured and blind no operation should be undertaken immediately unless they are causing great pain or for some reason life is endangered by keeping the remains; neither of which conditions is likely to occur. It serves no useful purpose to inflict, immediately after the shock of injury, the depression which would follow the knowledge that both organs of sight have been taken away. Such patients may be told that both eyes have been badly bruised, and they will gradually come to the knowledge that the rest of their life is to be spent in darkness. Exception may be made in the case of those transverse wounds of the head where one eye is whole though blind from division of the optic nerve, and the other blind from rupture or wound. The latter should be removed to prevent the possibility of sympathetic inflammation in its fellow, a condition which may give rise to pain and the possible necessity of excision.

Penetrating wounds with prolapse of iris, ciliary body, choroid, or lens capsule.—If an eye with such a wound is blind, it should be excised. If there is useful vision an attempt should be made to remove the prolapse, *but only by those who have special ophthalmic knowledge and who have the necessary instruments for the purpose.* These cases afford one of the few opportunities for conservative ophthalmic surgery in warfare; when skilfully dealt with an excellent result may be obtained, while incomplete surgical interference cannot, as a rule, be remedied by subsequent operation, and may easily lead to disaster. The nearest ophthalmic specialist should be sent for without delay, or the patient sent at once to a base ophthalmic department. The sooner the operation is undertaken the greater is the chance of removing the uveal tissue cleanly from the lips of the wound; the longer the delay, the tougher will be the adhesions. As mentioned above, it must be borne in mind that a penetrating wound of the globe following an explosion is practically a proof that a foreign body has entered or passed through the eye. (*For treatment of* foreign body in the eye, *see* below.)

Prolapse of the iris.—In operating on a prolapse our endeavour must be to pull out the iris so freely that, after cutting, the pillars of the iris retract away from the wound. Our aim is to leave not only no prolapse or entanglement, but not even an adhesion. An adhesion is a source of irritation and delays quiescence, while an entanglement and still more a prolapse is a positive danger and will demand further operation.

Prolapse of the ciliary body or choroid.—If clean, this should be replaced, and the sclera brought together by sutures; if it is ragged or obviously infected, it should be drawn out and excised before suturing. (N. B.—In suturing the sclera, a double-needled thread should be used, and the needles passed from within outwards through the superficial part of the sclera, taking great care not to include any uveal tissue, the lips of the wound being firmly held in toothed forceps to prevent escape of any vitreous while passing the needle.)

Prolapse or entanglement of the lens capsule.—This is often difficult to detect in the earlier stages. Any capsule which may be seen directly after the injury should either be drawn out and cut off, or tucked back into the anterior chamber. If only discovered in the later stages it may with advantage be divided with a sharp cutting needle.

Penetrating wounds without prolapse of uveal tissue.—If the eye is blind it should be excised. If there is a chance of saving useful vision, wounds of the sclera should be sutured; gaping wounds of the margin of the cornea cannot be sutured, but may be covered with a flap of conjunctiva.

Foreign bodies in the eye.—This group consists of some of the most as well as the least satisfactory cases. When the foreign body is magnetic and can be removed without delay by means of the magnet, a brilliant result may be obtained.

In military practice from about one-half of the cases with a foreign body in the eye the fragment can be removed with the magnet; in the other half we obtain no response, because the foreign body is non-magnetic, or is too firmly embedded in the coats of the eye, or incarcerated by inflammatory exudate.

Though many of the eyes from which a magnetic foreign body has been removed are too much damaged by the entry of the fragment to recover useful vision, yet when the removal has been performed skilfully the eye has a better chance of quieting down than when the particle is retained.

Use of magnet.—Since it cannot be known till trial is made with the magnet whether the foreign body is removable or not, and since the sooner the fragment is removed the better the result, every case in which it is suspected that a foreign body is in the eye should have the magnet treatment as early as possible. (The usual practice is to draw the fragment forward through the pupil into the anterior chamber by means of the large magnet, and then to withdraw it from the eye by means of a small magnet through a keratome incision made through the cornea. For details of the operation, *see* "Technique of Large and Small Magnets," Whiting and Goulden, first number 'Journal of Ophthalmology.') The removal of fragments by means of the magnets needs skill and dexterity in order to obtain the best results, and should only be attempted by those who have had special experience; serious damage can be caused by an ignorant use of this powerful apparatus.

If the presence of a foreign body in the eye is discovered or suspected when the patient is in an army area, the nearest ophthalmic specialist should be sent for, who will bring with him a large hand magnet. Should this not be available, either the patient should be sent forthwith to a base hospital where there is a magnet installation, or, if he be unfit to travel, the mobile magnet car should be sent for.

If the patient has reached a base hospital before the discovery is made, he should at once be transferred to the nearest ophthalmic department or the mobile magnet car brought to him.

Should embedding of a foreign body in the eye be complicated by prolapse or entanglement of uvea or lens capsule, or by a hypopyon, the fragment should first be extracted and the prolapse or entanglement, together with any wound of the sclera, dealt with afterwards. A hypopyon may be gently irrigated away with warm sterilised normal saline solution through the corneal section.

When the foreign body cannot be withdrawn by means of the magnet, experience shows that in the majority of cases more harm is done by blindly searching with forceps than by leaving it alone. Though a certain number of eyes containing foreign bodies retain useful vision, the greater number undergo degeneration in the course of time.

After treatment is carried out on the ordinary lines, viz., absolute *rest in* bed, attention to the general health, the eye is dressed daily, *bathed with boric acid* or saline lotion, and covered with a sterilised *pad and lightly bandaged*; atropin ointment is applied sufficiently

often to keep the pupil well dilated; if there is much reaction, hot bathing (over the closed lids) is carefully carried out four or more times a day, combined with leeches or blisters on the temples.

If the eye is degenerating or is not quieting down by the end of 10 days or a fortnight, it is wise to enucleate. A greater licence may be allowed for those cases in which there is no entanglement of uvea or lens capsule and when the eye retains useful vision.

It is essential that all cases of penetrating injury, with or without foreign body, in which the eye is on its probation, should be kept under the careful supervision of an ophthalmic surgeon; and, therefore, in evacuating to England, these cases should be labelled specially, in order that they may be sent to an ophthalmic hospital or to the ophthalmic department of a general hospital.

Foreign bodies in the cornea.—When deeply embedded these are often curiously troublesome to remove. A Beer's knife is the most useful instrument to employ, a needle is not stiff enough; a bright light should be well focussed on the cornea, and it is a great help to work with a magnifying glass. When the foreign bodies are very numerous and are not causing irritation, they should be left alone and the cornea treated as if it had been tattooed. If they are causing irritation each one must be picked out.

Foreign bodies in the orbit.—Fragments in the orbit may cause hæmorrhage or set up more or less severe cellulitis with proptosis and limitation of ocular movement. In a large number of cases, however, the swelling rapidly subsides under fomentations, and the foreign bodies cause no trouble. In these cases much more harm can be done by hunting for them than by leaving them alone. When the cellulitis is severe or increasing, it must be treated, after X-ray localisation, by incision, drainage, and removal of the fragment.

Localisation by X-rays.—Though ideally it would be well to know in each case before using the magnet in what part of the eye the foreign body is situated, yet in practice when dealing with smaller foreign bodies localisation is (as a rule) of secondary importance to an early use of the magnet. In times of pressure to have every case localised before being put up to the magnet would cause serious delay and over-pressure to the X-ray department. It is in cases where the magnet has failed to move the foreign body that an accurate localisation is of special value to tell us whether the foreign body is in the eye or has passed on into the orbit, and if it is of such size and so situated as to render advisable an operation for its removal.

The only exception to this is when from the size of the wound it is judged that a foreign body is of so large a diameter that it would do serious damage if drawn forward into the anterior chamber. In these cases it is well to have a preliminary localisation, and the foreign body can then be extracted, if it is thought desirable, through an incision in the sclera made as close as possible to the fragment.

Method of excision of the eye in the presence of panophthalmitis and orbital cellulitis.—If the eye is excised in the ordinary way with division of the optic nerve in the presence of orbital cellulitis, or where there is panophthalmitis, a definite risk is run of causing septic meningitis and death.

The following modification will be found a simple procedure, and one free from risk:

1. The contents of the globe are thoroughly eviscerated, all traces of retina and choroid being scraped away to avoid any chance of sympathetic ophthalmia.
2. The muscles are divided.
3. The sclerotic is pulled forward and divided far back, leaving only a frill round the intact optic nerve.

The actual procedure may be varied according to the following circumstances:

(*a*) When the opening in the globe is small, or has firmly healed and the contents are not septic, the conjunctiva and muscles are divided first, as this is of course much more simply done while there is some tension in the globe. The cornea is then cut away and the contents of the eye carefully scraped out, either with a large sharp spoon or with a scoop made for the purpose, and the process completed by scrubbing out the sclera with a swab held in a pair of forceps. The sclerotic is drawn well forward by two or three pairs of pressure forceps and cut far back, leaving a frill round the nerve as described above.

(*b*) If there is panophthalmitis, it is well to eviscerate the eyeball before dividing the muscles, to prevent the pus infecting the orbit. Therefore, after dividing the conjunctiva, the cornea is next removed by transfixing and cutting upwards, and then separating the lower half with scissors. The contents are completely scraped out, as described above, and the shell of sclerotic and conjunctiva thoroughly washed. The sclerotic is now packed firmly with a strip of gauze to facilitate the division of the muscles, which is next

performed. The gauze is then removed, the sclera drawn well forward, and divided as before.

The same method applies in the case of an open wound or rent of the eye.

(*c*) Where the globe is split open in many directions, as is often the case when a bullet has passed through it, packing is impossible. In this case, after scooping and wiping out the contents of the eye, the separate portions of the sclera can be picked up and made taut with pressure forceps, and the muscles dissected off. After drawing the bunch of forceps forward, the sclerotic is now cut through as described above.

The three points to keep in mind are:

1. To remove all traces of retina or choroid;
2. To take away the bulk of the sclerotic; but
3. To leave a frill of sclerotic round the intact optic nerve.

In this way all risk of infection of the nerve sheath and the meninges, as the result of the operation, is avoided; there is very little bleeding, the shock due to cutting the optic nerve does not occur, drainage for the cellulitis is afforded, and the healing process is not prolonged by leaving the bulk of the sclerotic, as in ordinary evisceration.

Warning against packing the orbit after excision of the eye.—After excision of the eye, packing of the orbit with gauze, a practice adopted by some, is found by experience to be both unnecessary and harmful. It is unnecessary, since any hæmorrhage which may occur can easily be controlled by a good sized pad firmly bandaged over the closed lids; and it is harmful, since it causes a sunken socket, by bringing about absorption of the orbital fat, and also the removal of the gauze is usually so painful as to necessitate the giving of an anæsthetic.

Section XVII.—INJURIES TO THE MEMBRANA TYMPANI DUE TO SHELL EXPLOSIONS.

In these injuries the deep meatus and the broken tympanic membrane must be left absolutely at rest. A light application of 2 per cent. iodine solution in spirit should be made to the cartilaginous portion of the external auditory meatus, care being taken that none of the fluid reaches the deeper part of the canal. The outer part of the meatus should then be plugged lightly with cotton wool. Syringing or the introduction of drops of lotions, especially hydrogen peroxide, are all dangerous. Such applications, beyond being painful, are very apt to give rise to acute inflammation of the middle ear, or actual suppuration.

(*c*) By regimental arrangements ensuring that, so far as is possible, men enter the trenches warmly clad in dry boots, socks, trousers, and puttees, and with the skin well rubbed with whale oil or anti-frostbite grease.

(*d*) By provision of warm food in the trenches when possible.

(*e*) By movement when possible, so as to maintain blood circulation.

(*f*) By the provision of warmth, shelter, hot food, and facilities for washing the feet and drying wet clothes for men leaving the trenches.

4. In order to minimise the prevalence of chilled feet and frostbite, commanding officers will be held responsible that the following instructions are carried out unremittingly and under the strictest supervision:

(*a*) Before entering the trenches, feet and legs will be washed and dried, then well rubbed with whale oil or anti-frostbite grease and dry socks put on. It is of the utmost importance that whale oil or anti-frostbite grease should not merely be applied, *but thoroughly rubbed in until the skin is dry*. Unless this precaution is systematically carried out the oil and grease become in a great measure valueless.

(*b*) A second pair of dry socks will be carried by each man, and, where possible, battalion arrangements will be made for socks to be dried and re-issued during each tour of duty in the trenches.

(*c*) While in the trenches, boots and socks will be taken off from time to time, if circumstances permit, the feet dried, well rubbed, and dry socks put on.

(*d*) On no account will hot water be used, nor the feet held near a fire.

(*e*) Where possible, hot food will be provided during tours of duty in the trenches.

(*f*) Where circumstances admit, long gum boots will be put on while the men's feet are dry before entering wet trenches, in order that men may start their tour of duty with dry feet.

(*g*) When gum boots are worn, it is well to support the socks by some form of fastening such as a safety pin, to prevent them from working down under the heel. On no account *will anything* in the form of a garter be worn.

(*h*) Where conditions are favourable, regimental rest posts will be instituted in proximity to the trenches, where men who show signs of suffering from exposure can be promptly attended to.

5. Under brigade arrangements, provision will be made for the washing and drying of feet in reserve billets, for the exchanging of wet socks for dry ones, and, if possible, the sending of the latter to the trenches, and for drying and brushing clothes. Steps will be taken to ensure that men make use of these arrangements.

6. Long gum boots are being issued to the fullest extent of the supply available, and every effort will be made to procure all that are necessary for men holding water-logged trenches. It is pointed out that the distribution of these boots depends upon the necessity for their use according to the nature of the trenches held by divisions, brigades, etc., and that therefore the distribution will be made not according to the numerical strength of formations, but according to the nature of the trenches which formations are required to hold. It has been noticed that men wear these boots in billets and localities a considerable distance behind the trenches. Long gum boots are solely for the use of men in the trenches, and will not be issued to, or used by, men under any other conditions.

"Trench feet" present very varied conditions, and these are partly dependent on the general health and circulation and the resistance of the individual, but chiefly on the length of exposure and the degree of cold. The worst cases, and the largest numbers, have generally occurred when the troops have been first thoroughly wetted by heavy rain, and when, subsequently, there has been a sudden change to clear weather and several degrees of frost.

In slight cases (*a*) the foot may present no abnormal appearance, but is the seat of severe pain and of acute cutaneous hyperæsthesia; (*b*) the whole foot is swollen, and although at first it is cold and so numb as to be practically anæsthetic, it soon becomes very red and hot, so that it presents the appearance of a large "chilblain," and to this affection "trench foot" of this degree is very closely allied.

In severe cases the foot is always swollen, and the swelling may extend nearly as far as the knee. Here, also, the whole foot is absolutely numb at first, and becomes very painful after an interval of a day or more in a billet or field ambulance. It is quite common for men to have no feeling of anything wrong with the feet while they are in the trenches, even though the toes are already dead.

In many cases of the swollen type blisters occur, and in bad cases they are both large and numerous. In yet worse cases the toes may be purple or black, and the same colouring may extend to a half or the whole of the foot. It should be carefully noted, however, that in *many such cases the blackness does not indicate deep gangrene*, and the very great majority of blackened toes are not to be regarded as wholly gangrenous. Most of them recover.

In the minority of cases one or more of the toes dies, and in a few cases a half or the whole of the foot becomes completely gangrenous.

When the toes are dead they often remain dry and shrivelled, but when the foot dies it is more often moist and very foul.

Prognosis of patients with trench feet is always difficult, but it may be said that, while apparently slight cases are often very long in recovering, bad cases with apparent gangrene are usually not so bad as they at first appear.

Even under favourable conditions and treatment most of the cases included above as "slight" usually require several weeks to recover, and many take several months. If a patient with definite, although slight, trench feet is sent back to the trenches within a few days, he is usually again invalided with a worse attack within a week. For a long time after an attack is apparently recovered from, the patient remains unduly susceptible to cold and wet.

Treatment.—Prevention is very much easier than cure. In slight cases the only thing necessary is to allow the patient to lie down so as to keep the feet elevated. In all cases the feet should be most carefully and thoroughly washed with soap and water, followed by an antiseptic lotion, and *an injection of antitetanic serum* must always be given, as not a few of these patients have developed tetanus. After washing, the skin should be painted with a 1-per-cent. solution of picric acid in spirit. When the feet remain cold and numb they should be frequently rubbed and, in the interval, wrapped in cotton-wool. If they are red and hot they are often best left exposed, for wrapping in wool only aggravates the pain. Bullæ should be punctured and dressed with some antiseptic. The foot may be enveloped in "Ambrine" if blistering is extensive. Pain is often relieved by aspirin or by salicylates in large doses. In later stages slight cases are much benefited by a course of electrical treatment, especially the high frequency current, and massage.

Gangrene of toes is best treated by amputation of the toe or toes after waiting a week or more for the circulation of the foot to be improved.

In cases *of apparent gangrene of the foot it is never right to amputate at once*, for in the great majority of such cases most of the foot recovers. If the gangrene is dry it is well to wait for a "line of demarcation," but if moist it is often necessary to amputate earlier. In very few cases is an amputation through the leg required. Syme's amputation can generally be performed even in the worst cases.

Section XIX.—TETANUS.

The heavily manured soil of the districts in which the fighting has occurred in France contains the spores of tetanus bacilli; these, in many wounds, are driven deep into the tissues, and may find there conditions suitable for their development. Should the bacilli which develop from these spores succeed in establishing themselves in such a wound, they give rise to a toxin which, from its great affinity for nervous tissue, produces the well-known symptoms of the disease.

PREVENTION.

A. *General measures.*—The steps advocated in other parts of this memorandum for the thorough surgical cleansing of the wound, the free removal of devitalised tissues, of foreign bodies and pieces of clothing, the arrest of hæmorrhage and the removal of blood clot, together with the appropriate methods of dressing and drainage, are those which, if fully carried out, will also minimise the risk of tetanus. They need not, therefore, be further described.

B. *Special measures.*—These resolve themselves into the prophylactic use of tetanus antitoxin, a proceeding which has proved of incontestable value throughout the war, and which is now universally employed by ourselves, our Allies, and the enemy.

PROPHYLACTIC USE OF TETANUS ANTITOXIN.

In the first two months of the war it was found that the incidence of tetanus among the wounded was much higher than had been anticipated from the experience of recent campaigns, and it is now clear that this was chiefly due to two causes, the greater severity of the wounds and the heavier contamination of the soil. As soon as this was realised it was decided to give a dose of antitoxin to every wounded man, irrespective of the nature of his injury, in place of leaving this, as had at first been done, to the discretion of the medical officer. The results have been excellent, and since this order came into effect the incidence of this grave disease among our wounded has been kept within very narrow limits.

Dose of antitoxin.—The prophylactic dose of antitoxin should be inoculated subcutaneously at the earliest possible moment in the case of every wounded man, no matter how trivial the injury may appear to be. Omission of the injection, on the ground that the wound was slight and appeared to be perfectly clean, has not infrequently resulted in an attack of tetanus. The customary prophylactic dose has been 500 units, one-third of the contents of a 10 c. c. phial containing 1,500 units, and, in the very great majority of cases, this has been found to confer adequate immunity. In severe wounds, however, and particularly in the case of deep wounds, or those which are much contaminated by dirt, or in which there is fracture of bone, a larger initial dose is desirable, and to such cases 1,000 or 1,500 units should be given. In the case of wounded men who have "lain out" in no man's land for several days, and in whom the danger of infection is obviously much enhanced, instructions have been issued that a dose of 1,500 units must be given at the earliest possible moment, and, further, that if there should be any special reason to anticipate the onset of tetanic symptoms intensive antitoxin treatment should be commenced forthwith.

The fears entertained in some quarters that anaphylactic shock might result in the case of men wounded for a second time, who had previously had an injection of antitoxin, have proved groundless, and injections should never be withheld on this ground.

Tetanus from accidental wounds.—In addition to wounds classed as "battle casualties," there are naturally a great number of accidental injuries which may also become contaminated with tetanus spores. A considerable number of cases of tetanus have occurred in men so injured, particularly in the case of those whose injury was so slight that they did not report sick, and therefore received no prophylactic dose of antitoxin. The mortality among such cases has been exceptionally high, and medical officers should be on their guard not to omit this needful precaution in all cases coming to their notice, and should warn the men under their charge to report such injuries promptly.

Tetanus from trench feet.—Another class of case, that of trench foot, has shown that the serious degree of devitalisation of the tissues which often accompanies it, affords good opportunities for the development of tetanus spores, should these gain an entrance. As soon as this was realised, directions were issued that all cases of trench *foot showing any skin lesions* should be inoculated. A certain num-

ber of cases, however, still continued to be reported, even in men in whom no such lesions could be detected. The order was then extended to cover every case of this affection, irrespective of the condition of the skin, and since then hardly a case has been reported.

Repetition of the prophylactic dose.—The passive immunity conferred by the initial dose of antitoxin passes off by degrees, and little is left at the end of 10 days. On the other hand, it is known that tetanus spores, like those of other anaërobes, may retain their vitality for long periods in the depths of a wound, particularly in connection with fragments of bone or with unsuspected bits of clothing.

Second dose of serum.—At a later stage of the wound, sometimes even after it has cicatrised, some change in the environment of the spores may give them their chance to germinate, and an attack of tetanus may result. A repetition of the initial dose at regular intervals would therefore appear to be sound policy, and second, third, and fourth doses, of 500 units, at intervals of from seven to nine days, are directed to be given to all wounded who are transferred to home hospitals. The same rules should be observed in France in the cases of those who remain under treatment over six days from the receipt of their injury, but exceptions have been authorised in the case of men whose injuries are so slight that they can be discharged in a few days to convalescent camps, or even to duty. Every effort should, however, be made in these cases to see that the man gets at least a second dose on the seventh day, or as soon after as can be arranged.

Serum before operation.—The possibility of a secondary operation, exposing the patient to the dangers of an attack of tetanus by disturbing a focus in which spores may have been lying dormant, should not be forgotten. A number of cases have been reported in which, even after an interval of months from the receipt of the wound, and after the original wound is firmly cicatrised, an attack of tetanus has followed. It is well, therefore, when such an operation is contemplated, to give a preliminary inoculation of 500 units, subcutaneously two days beforehand, or, if a more rapid effect is required, the intramuscular route may be employed, and the dose given the day before the operation.

SYMPTOMS.

In order to obtain the best results from whatever system of treatment may be adopted, it is most essential that it should be

commenced at the earliest possible moment. Naturally, this implies the prompt recognition of the first symptoms of the disease, and this is often by no means easy. By the time the classical symptom of trismus has made its appearance, much valuable time may have been lost, and it is certain that the best results of antitoxin treatment are directly associated with the promptitude with which its administration has been commenced.

Our knowledge of the early symptoms of tetanus is by no means as full as we could wish, but information upon this point is being steadily accumulated from the returns which are received in connection with the cases occurring both in France and at home. These early indications may be of a general nature, such as irritability, insomnia, increased reflex excitability, or muscular tremors; or they may be local, and manifest themselves as pain in or near the wound, increased hardness or rigidity of the muscles in its neighbourhood, with twitchings of various muscles, easily excited by various stimuli. Other early symptoms which should be watched for are sore throat, difficulty in swallowing, pain or stiffness of the neck, and perhaps other local evidences of reflex spasm or paralysis. Difficulty of micturition due to spasm of the sphincter has also heralded an attack. Of these, the most frequently noted are the local signs of spasm and rigidity in the muscles near the wound, and it is probable that, in inoculated men, a certain number of these cases of local tetanus do not progress to a generalisation of the disease, and escape record. Medical officers and nurses should, however, keep the closest watch for their occurrence, and specific treatment should be started without delay.

TREATMENT.

The various lines of treatment may be dealt with under the following heads:

A. *Local and surgical measures.*—The local application of antiseptics of various kinds, though probably of indirect service in combating co-existing sepsis, cannot be relied upon either to kill the tetanus bacilli in the deeper parts of the wound or to neutralise their toxins. The application of pure carbolic acid and the free use of peroxide of hydrogen have proved of very doubtful value. As *regards surgical intervention* after tetanus has declared itself, it is *now generally accepted* that the less there is of this the better.

Beyond ensuring that the wound is freely opened and well drained, and that decomposing blood-clot, foreign bodies and bone splinters are removed, it is doubtful whether surgical intervention of a graver nature is justifiable except when life is directly threatened by some other condition or complication. It is better, if possible, to delay such operations until the tetanic symptoms have passed away, or at least until the system is well saturated with antitoxin. In a recent series of 353 cases of the disease, operative procedure of a more or less grave nature was carried out, subsequent to the appearance of tetanic symptoms, in 27. Of these 22 died and 5 recovered, a mortality of 81.48 per cent.

B. *General measures.*—The patient should be kept in a perfectly quiet and darkened room, maintained, if this can be arranged, at an equable temperature. The avoidance of all external stimuli, likely to start a spasm, is to be aimed at, and some have advocated such measures as bandaging the eyes, plugging the ears with cotton wool, and placing the feet of the bed on rubber discs, with this object in view. It is of great importance to maintain the strength of the patient by means of adequate fluid nourishment, given in small quantities at frequent intervals, and by the rectum if swallowing tends to produce spasm.

C. *The use of anæsthetics and sedatives.*—As regards the former, chloroform has been most commonly used, though ether has been preferred by some, especially when required for a small operation or for the dressing of a painful wound. Their value is well recognised. As sedatives, chloral hydrate, potassium bromide and morphia are most frequently used for controlling spasm, the first-named being regarded as the most valuable. They are of undoubted value, but they do not appear to modify the course of the disease to any great extent. It must also be remembered that too frequent or too large doses of any of them may be harmful. Chloretone, in doses of 30–40 grains in olive oil, given by the rectum, was at one time advocated, but it has been disappointing, and is now seldom used.

D. *Carbolic acid method.*—This method was given a trial in a number of cases in the first year of the war, usually in combination with antitoxin treatment, but, although a case here and there appeared to benefit, it has been found to be quite unreliable, and no case in France has been treated by it for many months. The following strengths were employed, the inoculations being made either subcutaneously or intramuscularly every three or four hours, the interval

between the doses being lengthened if the spasms diminished in frequency:

(i) 20 c.c. doses of a 1 per cent. solution.
(ii) 20 minim doses of a 2 per cent. solution.
(iii) 2 c.c. doses of a 5 per cent solution.

E. *Magnesium sulphate.*—Three methods of employing this drug have been advocated: (*a*) the subcutaneous inoculation of doses of 2 c.c. of a 25 per cent. solution; (*b*) the subcutaneous inoculation of large quantities of a 1 or 2 per cent. solution, from a pint to a quart being given every three hours, according to the severity of the case; (*c*) the intrathecal method. For the last, Phillips recommended the introduction into the theca of 1 c.c. of a 25 per cent. solution for every 25 lbs. of body weight, corresponding to 5 or 6 c.c. for a man of average size. These methods, however, aim at no more than the control of spasm, they have no curative effect, and their use is not free from danger; like the carbolic acid method they are now hardly ever used.

F. *Tetanus antitoxin.*—The specific treatment of tetanus stands on a different footing from the non-specific and it has been almost universally employed in the cases which have arisen during the war. When recovery has resulted, this, in a large proportion of the cases, has been attributed by the reporting officer to the use of antitoxin, and in many cases it is impossible to doubt its good effects. At the same time it must be admitted that it frequently fails, even when given in enormous doses. From the very early days of the war the closest attention has been given to this subject and full reports are called for, both in the Expeditionary Force and at home, of the details as to the employment of antitoxin therapeutically. These reports have been submitted to analysis and a number of these have from time to time appeared in the medical press. Attempts have been made to draw useful conclusions as to the best mode of administering the antitoxin, and the most suitable system of dosage, but the interpretation of the results has proved extremely difficult, and we are not in a position to lay down precise rules on the subject. Three cardinal principles, however, are clear; the antitoxin treatment must be started immediately after the appearance of the first suspicious sign of tetanus, the dosage of the antitoxin must be high, and its use must be maintained well into convalescence. The first principle has already been alluded to in connection with the great

importance of watching for and detecting the earliest symptoms of the disease, the administration of a dose of antitoxin at this moment may be worth a ten-fold dose given 24 hours later, when the toxin has had time to reach and poison the cells of the central nervous system.

In spite of the uncertainty as to the optimum method of antitoxin administration it is probable that the increasing observance of the three principles just mentioned is largely responsible for the steady decline in the case mortality of the disease. In a series of reports upon cases of tetanus developing in home hospitals during the war, published by Surgeon General Sir David Bruce, the case-mortality rates run as follows:

	Cases.	Deaths.	Case mortality.
			Per cent.
First series	231	133	57.7
Second series	195	96	49.2
Third series	200	73	36.5
Fourth series	100	31	31.0
Fifth series	100	19	[1] 19.0

[1] In this series are included 19 cases of local tetanus, all of which recovered.

In a similar series of reports of cases which have occurred in France, naturally inclusive of a much higher proportion of gravely wounded men, and of cases in which death has been accelerated or caused by such conditions as gas-gangrene, severe sepsis, secondary hæmorrhage, &c., the following have been the rates:

	Cases.	Deaths.	Case mortality
			Per cent.
First series	179	140	78.2
Second series	160	118	73.7
Third series	353	238	[1] 67.4

[1] Not yet published.

Channel of administration.—The four following routes, either alone or in combination, are those commonly employed, intrathecal, intravenous, subcutaneous and intramuscular. In the series of analyses just mentioned the records have been very closely examined in an endeavour to determine which of these, or which combination of them, had given the best results. The task has been one of extreme difficulty owing to the existence of so large a number of complicating factors in each case. The conclusions drawn even from a group of several hundred cases may fail to be substantiated by comparison with those drawn from another group of similar dimensions. The subject is too involved to allow of adequate treatment in a Memorandum such as this, and a few remarks only will be made under each head.

(i) *Intrathecal method.*—The Memorandum on Tetanus issued by the War Office Tetanus Committee makes the following statement. "In acute general tetanus the best method of treatment lies in the earliest possible administration of large doses of antitoxic serum by the intrathecal route, repeated on two, three or four days in succession, and combined, if thought desirable, with intramuscular injections." Experience of the intrathecal route in France has not been so favourable and doubts have been expressed by some surgeons as to the wisdom of giving these repeated intrathecal injections. From the theoretical standpoint, as well as from the results of animal experiment, the method is sound, but it would appear that its value is likely to be highest if the case is diagnosed sufficiently early to allow of its prompt application. Once the disease is established its further employment has, in France, proved very disappointing.

(ii) *Intravenous method.*—Direct injection of the antitoxin into the veins is obviously the most rapid means of attempting to neutralise the tetanus toxin circulating in the system, but it has the disadvantage that, in those who have had previous inoculations of horse serum, the danger of anaphylaxis is greater than by other methods. The method is not recommended; of 11 cases treated in France by this channel only, all died.

(iii) *Subcutaneous method.*—This method, as well as the intramuscular, is free from several of the objections to which Nos. (i) and (ii) are open, but absorption of the antitoxin is slow and is said to require 48 hours before the maximum concentration is reached in the blood. Large quantities can, however, be given

by this channel, at frequent intervals, so that the degree of concentration in the blood-stream can be maintained at a high level.

(iv) *Intramuscular method.*—Absorption of the antitoxin is more rapid by this channel than by the subcutaneous, taking, it is said, about 12 hours; by it, also, the serum may readily be introduced at various points near the wound, and consequently close to the site at which the toxin is being formed.

The following table gives the total number of instances in which one only of the above methods of introduction of antitoxin was employed throughout the case. They have been collected from all available sources, published or unpublished, dealing with the incidence of tetanus in our army during the war. They are taken from a total of 1,192 cases of tetanus in which antitoxin was a part of the treatment employed.

	Cases.	Deaths.	Case mortality.
			Per cent.
Intrathecal only	90	63	70.0
Intravenous only	31	23	74.1
Subcutaneous only	265	146	55.0
Intramuscular only	86	34	39.5

Dosage.—This should be large and constantly renewed. Whatever route or combination of routes may be chosen it is desired to bring about a saturation of the tissues with antitoxin at the earliest moment and to maintain this until all danger is past; 50,000 units or more may be given in the first 48 hours, and the daily dosage, which will naturally depend largely on the progress of the case, may be reduced until, towards the seventh or eighth day, doses of from 1,000 to 2,000 units may be given on alternate days until all tetanic symptoms have disappeared. Care must be taken not to stop the treatment too soon, as cases have occurred in which such a cessation was followed by a relapse, possibly fatal.

No precise instructions can yet be laid down, however, either as to the optimum dosage to employ or as to the best way in which to give it. Careful analysis of these points in a series of cases is handicapped by the fact that, while we know accurately the dose

of antitoxin which has been given, we are in complete ignorance as to the dose of toxin which we are aiming to neutralise. If the intrathecal method is chosen, at all events at the beginning of an attack, the concentrated serum which is usually available should be employed. This contains 8,000 units in about 10 c. c., so 20 c. c. injected very slowly into the canal will introduce 16,000 units. At the same time it is well to combine this with, if not to replace it by, large and regular intramuscular or subcutaneous doses of antitoxin of the ordinary strength, *i. e.*, 1,500 units to the phial of about 10 c. c. The more rapid absorption by the intramuscular route should be borne in mind and also the possible advantage of introducing the antitoxin in the neighbourhood of the wound or wounds.

For the treatment of local tetanus, daily subcutaneous or intramuscular doses of about 5,000 units may suffice, but if there is any sign of generalisation of the disease, the advisability of an intrathecal injection may be considered.

It may be added that, owing to the necessity for keeping up a large stock of antitoxin, samples are sometimes encountered older than the "date of expiry" marked on the phials. Careful tests have from time to time been made as to the maintenance of strength of the various brands employed. In general, these tests have shown that tetanus antitoxin preserves its potency considerably better than had been anticipated. Instructions in connection with these batches have been issued to all concerned, and, where necessary, the additional dose required is marked on the phial and the date beyond which it may not be used.

Anaphylaxis.—As has already been stated, there is no support from our experience in France that this condition is to be feared when a man who has been wounded on a former occasion receives once more a subcutaneous prophylactic injection. The intravenous and even the intrathecal route are, however, not so free from danger if an interval of more than ten days has elapsed since the last dose of antitoxin, and two fatal cases have been recorded in the last series of cases in France, in each of which the intravenous channel had been employed.

In cases in which there is reason to fear the occurrence of anaphylactic shock, various procedures have been recommended to lessen the danger. The majority of these are "fractional" methods of *administering the serum*, a preliminary inoculation of two or three *drops being given in dilution*, followed in five minutes by a dose of

0.5 c. c. If no untoward symptoms result, it is said that the full dose may safely be inoculated ten minutes later. A similar fractional method has been advised if the intravenous or intrathecal routes are to be employed, but there has been no opportunity of judging their value. Administration of the antitoxin under chloroform anæsthesia is also said to be a safeguard, though this has been questioned.

If symptoms of anaphylactic shock should develop, such as collapse, pallor, sweating, air-hunger, rapid and failing pulse, cyanosis and respiratory failure, adrenalin has been stated to be useful, given intravenously in high dilution if the symptoms are urgent, hypodermically in less urgent conditions, in a dose of a few minims of a 1–1000 solution. Pituitrin, in a dose of 1 c. c., has also been stated to relieve collapse and spasm of the bronchioles if given immediately on the appearance of the symptoms.

Section XX.—P. U. O. AND TRENCH FEVER.

Fever of indeterminate character is the cause of a very large proportion of the sickness of the Army. For every case of any enteric fever there are probably 20 in which there is no evidence, clinical or bacteriological, of any form of enteric, or of any of the other known fevers.

Character of pyrexia.—These cases fall into three classes.

Class A.—Trench fever is a relapsing fever, with short bouts of 2–5 days' duration, separated by normal, or nearly normal, intervals. The incubation period is probably 2–3 weeks. The onset is nearly always sudden, and the temperature usually reaches its maximum on the first, but sometimes not till the second, day. It rises to 101°, 102°, or 103°, and, in exceptional instances, has been found as high as 105° and 106° F. The fall is a little less rapid, and is commonly completed by the fourth or fifth day. After an interval of a day or two a fresh rise begins. It is rare to get more than four bouts. In some cases the temperature remains irregular long after the definite bouts have ceased.

Initial symptoms.—The onset is almost invariably sudden, with headache, usually frontal, referred most often to the back of the eyes. In many patients the conjunctivæ are congested, producing the "pink eye." The headache is accompanied by general malaise, or by local pains in the back and lower limbs. At the same time, there is often dizziness or some similar feeling. Many actually fall down, others are unable to walk, and some faint. There is often shivering, and not infrequently vomiting. A few cases have transient diarrhœa. The same symptoms occur in the relapses.

Pains.—In the intermittent periods some patients feel well. But in other cases pains persist throughout, and sometimes last long after the relapses have ceased. Headache is the most persistent. The other pains are more variable in site and more fleeting. The lower limbs are much more commonly painful than the upper. The thighs, calves, and shins are favourite parts. Pains referred to the shins occur in about half the cases. The pains often prevent sleep.

Painful parts are sometimes tender. Some cannot even bear the weight of the bedclothes. In many the shins, and in some the calves,

are tender to pressure, but there is no evidence of periostitis or neuritis.

In a few, hyperæsthetic zones have been found which correspond to the distribution of one or two dorsal or lumbar roots. Sometimes there are ill-defined areas of hyperæsthesia on the legs or trunk.

The left hypochondrium is sometimes the seat of pain. This may be due to enlargement of the spleen.

Eruptions.—Herpes round the mouth is not uncommon. Small roseolar spots, paling on pressure and not projecting, have been often seen. They have been thought to be evidence of enteric, but it is clear that they are not. They sometimes recur in the relapses.

Alimentary.—The tongue in the first few days has a yellowish or brownish fur on the dorsum, with red edges. There is anorexia at first. Constipation is the rule.

Respiratory.—In winter, when coryza and bronchitis abound, they are found in these patients, but at other times, the respiratory system is unaffected.

Urinary.—In a few cases there is a slight transient albuminuria when first admitted, but no more than is seen in other febrile diseases.

Splenic enlargement.—In 1915 the spleen was not palpable in this disease. But in 1916 it was felt below the ribs in several cases, and in 1917 it was palpable in about a third of the whole number. It has been felt on the first day, and it has in some cases remained palpable for three weeks, though usually disappearing sooner.

Circulatcry.—The pulse at first follows the temperature, rising to 100 or 110 in the bouts and falling to 60 or 70 in the intervals. But at a later period it often rises independently of the temperature, and in about a third of the cases severe tachycardia occurs. Though this may begin when the patient is still in bed, there is no doubt that it is far more frequent if he gets up before the 21st day. It is often accompanied by a displacement of the apex, sometimes to an inch outside the nipple, and occasionally a bruit has been heard. Præcordial pain has been found in some of these patients. This condition sometimes lasts many weeks and is probably the explanation of a good many cases of disordered action of the heart. It is therefore good economy to keep any serious case in bed for three weeks, even though his general condition seems favourable. There is no evidence that endocarditis ever occurs.

A certain number of patients become greatly weakened by the *disease.*

Remittent form.—In about a third of the cases marked by definite relapses, the temperature does not quite reach the normal between the bouts.

Class B—Initial bout only.—Some cases which seem otherwise to belong to the first class show only one short bout and do not relapse, though they may like the others continue with a low pyrexia for a considerable time. Among a large number of cases carefully observed, no case was found in which the temperature of the first two days, if known, failed to show a definite initial rise. Splenic enlargement and tachycardia are as common in these as in the relapsing cases, and the other symptoms are the same. These, however, are the cases which are the most difficult to distinguish from influenza.

Class C—Prolonged fevers.—The third class of cases has a *prolonged initial fever* lasting from 6–20 days, but in most instances falling to normal between the 8th and the 14th day. It shows no regular relapses. *Any case of fever lasting over five days should be tested for enteric*, but there is no doubt that a large number of them show no evidence of that disease whatever.

Symptoms.—The symptoms of this class do not differ from those of the first, which after all are little more than the common denominator of all infectious fevers. The onset is sudden, the spleen is enlarged, and tachycardia is present in about the same proportion. Up to the present the character of the temperature chart is the only distinction. It must, however, be remembered that pain in the legs, and in particular, pain in the shins, is not peculiar to these classes. It has been well marked in some cases of enteric.

Diagnosis.—When enteric has been excluded by bacteriological and serological examination, the chief difficulty is the distinction of these cases from influenza.

The points of difference are:

(*a*) That influenza does not show the regular and definite relapses of trench fever.

(*b*) That influenza, though it has many forms, is typically a disease of the respiratory tract, whereas affection of this tract in trench fever is accidental.

(*c*) That the *B. influenzæ* has never been found in trench fever in spite of repeated search.

(*d*) That influenza is an infection that sweeps over wide areas, whereas trench fever was at first entirely and is even now almost entirely confined to the front area.

Pathology.—We have hitherto failed to find any organism that can be accepted as the cause of these fevers.

The relapsing character of trench fever suggests a protozoal infection.—Spirochætes have been found in the urine but are also found in the urethra of many healthy men. Nothing has yet been found in the blood, but experiments show that the infection may be transmitted by inoculation with the whole blood, the red cells, or the plasma of an infected patient. The fever begins about a week after inoculation. But when plasma is filtered through porcelain it is no longer infectious. The disease has now frequently been transmitted by means of lice. The incubation period in these cases is almost exactly three weeks.

Treatment.—No drug has yet been found that will stop the relapses or cure the pains. Salicylic compounds, including aspirin, though commonly employed are usually impotent, and so is quinine. Salvarsan and antimony have both been injected into the blood but without effect. Opium is the only effective anodyne. Some recommend compresses soaked in a saturated solution of sulphate of magnesia. If the case is at all severe ,the patient requires long care and should be sent to the base.

Section XXI.—INFECTIVE JAUNDICE.

Jaundice in war is usually caused by an infection. In France the majority of such cases fall into one of the following groups:

(*a*) Spirochætal jaundice.
(*b*) Enteric jaundice.
(*c*) Jaundice of acute septicæmia.
(*d*) "Catarrhal" jaundice (including certain indeterminate forms).

SPIROCHÆTAL JAUNDICE.

SYMPTOMS.

The cases may conveniently be divided into (*a*) severe, and (*b*) mild, though there is no sharp line of demarcation between the two groups.

Severe cases.—The clinical picture preceding the appearance of jaundice bears close resemblance to that of enteric fever, comprising prostration, headache, generalised pains, furred tongue, shivering, and occasional vomiting, with fever. These manifestations may develop abruptly or gradually, the sudden being rather more frequent than the gradual invasion. The jaundice usually appears on the 4th or 5th day, but it may be as early as the 2nd, and as late as the 7th day. Conjunctival injection, herpes labialis, and hæmorrhages are all distinctive features, especially the last named, though their presence is not invariable. Bleeding most often occurs in the first week, and may come from the nose, lung, stomach, bowel, kidneys, or as a purpuric rash. Early in the illness a slight hæmoptysis is a valuable diagnostic sign. The herpes may be hæmorrhagic. The spleen is seldom palpable, or the splenic region tender. The liver is moderately enlarged, and sometimes tender. In addition to bile it is usual to find albumin in the urine, and casts both hyaline and granular are not uncommon. The pulse is slow in proportion to the pyrexia—a rate of 75–85 being quite usual. In this respect the disease resembles enteric fever, though differing from the latter in

that the heart does not "lock" with atropine. The fever at the commencement rises to 102–103°, but the temperature tends to fall as jaundice becomes established, and about the 8th day will touch normal. In some cases this marks the end of the fever, while in others, after an interval of four or five days, there is a secondary rise, and the temperature may not permanently settle till the 3rd or 4th week. When the acute stage is over, the patient is weak and wasted; convalescence is slow, but recovery is complete.

A case doing badly is characterised by a dry brown tongue, sometimes by many hæmorrhages and a marked drowsiness, which may either increase until it passes into coma, or be interrupted by delirium or an occasional convulsion. Death may occur as early as the sixth or seventh day, or as late as the fourth week.

Mild cases.—The mild cases are now the more numerous, and, from their indefiniteness of features, more difficult to detect. They often begin quite severely with a sharp rise of temperature to 102–103°, and the prostration, headache, body pains, and vomiting above referred to. By the seventh or sixth day, or even the fourth day, the temperature will have fallen to normal and the acute symptoms will have subsided—the patient being jaundiced, weak, and depressed. Of the more distinctive signs, conjunctival suffusion is common, herpes labialis occurs in about half the cases, but hæmorrhages are rare.

Variety of the disease without jaundice.—Jaundice, though perhaps a usual, is not a necessary manifestation of this spirochætal disease, and some cases of "P.U.O." are doubtless due to the *Spirochæta ictero-hæmorrhagiæ*. Beyond the absence of jaundice, the clinical picture resembles that already given.

Meningeal symptoms have been observed in rare instances—a fact to bear in mind when investigating a case of suspected meningitis.

PATHOLOGY.

The toxæmia will alone suffice to destroy life. The anatomical changes produced by the spirochæte vary in their distribution and importance.

The liver is usually slightly enlarged, but occasionally is shrunken. The changes discernible by the naked eye are few, while those seen with the microscope show marked variation. In some cases *the disease* has fallen with slight force on the liver, and the arrange-

ment and structure of the lobules and bile ducts are normal, bile stasis being the only abnormal feature. In other cases the liver shows the effects of damage; there is loss of lobular pattern; the liver cells are dissociated, vary in size and shape, and some of them show two nuclei, and mitoses are numerous.

Some cases show obvious swelling and congestion of the duodenal mucous membrane, which is of a purplish red colour. These changes involve the papilla of Vater and the last ½ inch of the common duct.

The immediate cause of the jaundice varies. Where there is disorganisation of the lobules, with damage to the cells and intrahepatic ducts, the jaundice is caused by interference with the drainage of the bile within the liver. Where there are no changes within the liver, and there are inflammation and swelling of the duodenum and papilla of Vater, the jaundice is caused by obstruction of the outlet of the common duct. Where there are no definite changes in the liver, and no inflammation and swelling of the duodenum, jaundice is absent.

The kidneys show swelling and granular degeneration of the tubular epithelium, clear and hæmorrhagic exudate into the lumen of the tubules, and infiltration of polymorphonuclear leucocytes between the tubules.

In the lungs hæmorrhages of varying size are formed resembling those met with in cases of mitral stenosis. Scattered sub-peritoneal, sub-pleural, and sub-pericardial hæmorrhages are usual. The cause of this disease is the *Spirochæta icterohæmorrhagiæ*, for (1) the spirochæte may be found in the human peripheral blood stream; (2) injection of infected human blood into the peritoneal cavity of the guinea-pig produces a characteristic fatal illness in that animal, in whose tissues, *post mortem*, the spirochætes are present in large numbers; (3) the disease has been produced in man by accidental inoculation from such an infected guinea-pig; (4) after the first fortnight of the disease, the spirochæte may be found in the patient's urine.

The infection finds entrance through the mouth or the skin; the medium of such infection is either water or food. The spirochæte is commonly present in the urine of field rats, which, by the contamination of food, convey the infection. The urine of infected patients would likewise convey the disease if sanitary regulations

were not observed. The disease is more prone to spread in wet trenches.

Laboratory tests.—Direct examination of the blood is not of practical utility owing to the organism being only present for a short time and in scanty numbers.

Reproduction of the disease in the guinea-pig is the most convincing diagnostic evidence. The blood is only infective in the early days of the disease, seldom later than the seventh day, and in mild cases not as late. Hence the importance of applying the test the moment jaundice appears, and sooner if symptoms suggestive of the disease are present.

Inoculate a guinea-pig intraperitoneally with 3–5 c.c. of the patient's blood. In a positive case the animal, after an incubation period of 6–12 days, develops the disease and dies.

Examination of patient's urine.—These spirochætes are chiefly eliminated by the urine. They appear about the ninth day, reach their maximum about the fifteenth day, and disappear by the end of the fifth week. Collect the urine in a sterile vessel; centrifuge 50 c.c. of it; wash the deposit with distilled sterile water; recentrifuge, and make smears with the final deposit; stain by the Indian ink or collargol method, or better still, by the method of Fontana. To be reliable this method needs practice. It is necessary also to differentiate the specific spirochætes from the other bodies resembling them. Before spirochætes can be stated to be absent, the urine must be examined on several successive occasions. Though this method is valuable, it does not afford evidence as convincing as the production of jaundice in the guinea-pig.

Diagnosis.—(*a*) Early—Given a patient who becomes abruptly ill with headache, body pains, chilliness, fever, vomiting, he may have one of many infections; *e. g.*, enteric fever, trench fever, spirochætosis, influenza, etc. A gradual onset would suggest enteric fever or spirochætosis. As regards *influenza*, a tentative opinion can be formed, for the disease seldom exists without the development of the characteristic catarrhal manifestations in the upper respiratory tract.

Trench fever gives no distinguishing *early* clinical picture, and the fact that conjunctival injection and herpes labialis may both occur in this disease adds to the difficulty of early diagnosis. The pulse in trench fever follows the temperature, rising to 100–110, whereas in spirochætosis it remains relatively slow, as in enteric fever. After

the lapse of a few days the characteristic temperature chart of trench fever may put doubt aside. Local pains and areas of superficial and deep tenderness are more suggestive of trench fever. The appearance of hæmorrhages or jaundice would be decisive in favour of spirochætal disease. Cases of spirochætosis without jaundice are easily missed. Here examination of the urine affords help.

Enteric fever.—On account of its being an uncommon feature, jaundice is apt to disguise enteric fever. It may occur early or late in the disease. Only when it occurs early, viz., before the tenth day, does difficulty in differentiating between enteric fever and spirochætosis arise. Conjunctival suffusion and herpes labialis are evidence in favour of spirochætosis. Epistaxis may occur in either disease, but hæmoptysis, hæmatemesis, melæna or purpura are strongly suggestive of spirochætal infection, though in the milder cases of the latter this evidence is absent.

A palpable spleen suggests enteric fever, for in the latter it is common, whereas in spirochætosis it is rare. The characteristic spots point to enteric, but their presence is inconstant. Slowness of the pulse in proportion to the fever is a feature of both diseases. They, however, behave differently to atropine, after the administration of which the heart of enteric fever tends to "lock," and that of spirochætosis to "escape."

This effect usually becomes obvious at the end of the first week and continues till about the 15th day, though in some cases it may be limited to one or two days; 1/30 gr. atropine is administered hypodermically, and the increase of pulse rate is recorded every three minutes for the following hour. An increased rate of 10, or less, beats denotes "locking," or a positive result, an increase of 15 or more beats denotes "escape," or negative result. For the test to be reliable the rate of the heart must not exceed 85 before the administration of the atropine.

The early withdrawal of blood for culture or inoculation into a guinea-pig is of great importance, for the infectivity of the blood in both diseases is transient, especially in mild cases. Neither a culture negative to enteric fever nor a guinea-pig negative to spirochætosis is conclusive.

The examination of the urine for spirochætes is valuable, but only becomes available after the ninth day of illness.

In searching for enteric organisms in urine and fæces conclusions cannot be drawn from negative findings, unless after repeated exam-

inations. In triply inoculated patients valuable aid is afforded by variations of the agglutinations on at least three occasions separated by periods of four or more days.

"Catarrhal" jaundice has the features of an infection which has localised in the duodenum. The usual symptoms are headache, lassitude, transient fever, abdominal discomfort, anorexia, nausea, with jaundice supervening later. No doubt the same infection can exist without jaundice. It may present a clinical picture closely resembling enteric or spirochætal jaundice.

Treatment.—During the febrile period the patient should be encouraged to take generously of fluid, and an alkaline mixture is useful. For spirochætal jaundice an anti-serum has been prepared, and is available for use. Its merits are not yet established.

Section XXII.—NEPHRITIS.

In former wars, with the exception of the American Civil War, nephritis has not occurred to any serious extent, and in the present campaign very few cases were observed in the British Army until the spring of 1915. Since March, 1915, the disease has been prevalent, and at times, especially in the colder months, but not only then, large numbers of cases have occurred. Men belonging to all branches of the Service have been affected, and the disease has by no means been limited to men actually serving in the trenches. Many cases have occurred, especially in 1915 and 1916, in men serving on the lines of communication, or as hospital orderlies, who had at the time never been to the front. The malady is decidedly uncommon amongst officers, and it was practically unknown amongst the Indian troops whilst they were serving in France, although it was rife at this period amongst the British troops. In a series of 571 cases, 25.7 per cent. of the cases occurred in men under 25 years of age. It is clear, therefore, that large numbers of cases occur in young men, and that the disease is not one affecting only the older men. In a series of 326 cases, 195 occurred in men who had been in France six months or less, and 131 in men who had served in France from six to twelve months.

Causation.—The causation of the disease is obscure, there is no evidence that its incidence is connected with diet or water supply, and if it has any relation to exposure and fatigue it would seem that the relation cannot be a simple and direct one, since otherwise it is difficult to account for the escape of the Indian native troops, as they suffered considerably from such ailments as bronchitis, broncho-pneumonia, etc., that are directly dependent upon exposure to severe climatic conditions. In a series of 278 cases analysed to determine whether any illness, slight or severe, preceded the onset of dropsy, there was a history of a severe "cold," or of diarrhœa, or of influenza or sore throat, in 10.4 per cent. In 30 per cent. the patients give a history of or had distinct signs and symptoms of bronchitis, either at the actual onset or in the early stages of the nephritis, and

in some cases the bronchitis was severe. The bronchitis might be regarded as causally related to the nephritis, were it not for the fact that bronchitis was very common and severe in the native Indian troops, and yet no nephritis occurred. Previous renal disease is another possible ætiological factor and in a series of 571 cases a history suggesting that the patient had previously suffered from nephritis was obtained in 62 cases, *i. e.*, 10.8 per cent. Further, in many fatal cases, although diagnosed clinically as acute, chronic lesions have been found showing that the acute illness was superimposed on old standing chronic disease. This, however, is not true of all fatal cases, in some there can be no question that the lesion was entirely an acute one. There is no satisfactory evidence, as yet, of the presence of any specific infective agent, bacterial or other, either in the blood or in the urine in these cases. Hence the causation of the disease is as yet unknown, but the cases do not all belong to one and the same group clinically and therefore it is probable that more than one cause may be operative.

Morbid anatomy.—Lesions are present in the glomeruli, convoluted tubules and interstitial tissue, resembling, if not identical with, those seen in the nephritis of civil life. Hyaline degeneration and thrombosis are present in the glomerular vessels, and proliferation of the glomerular epithelium may also occur. In the convoluted tubules, the epithelium shows marked changes, the cells have lost their striation, stain badly or may be hyaline. Further, there is much shedding of the tubular epithelium. Hæmorrhage into and between the tubules is common, and the interstitial tissue is swollen, œdematous, and infiltrated with lymphocytes and polymorphs. In many cases the lesions in the kidney are indistinguishable from those usually present in the so-called large white kidney.

Clinical course.—In many cases the onset is apparently sudden, in others it is gradual. In the former dyspnœa is generally the initial symptom, and may be noticed first during exertion, *e. g.*, on the march, and then on examination the patient is found to be œdematous. In other cases, with a gradual onset, there is malaise for some days, followed by the development of dropsy. In exceptional instances some severe uræmic symptoms, *e. g.*, fits or amaurosis, have been the initial symptoms, but in many of, but not all, *such cases the disease is* really an exacerbation of an old chronic, *but latent, nephritis.* In a small but very distinct group the onset

is different, and is characterised by moderate pyrexia, 102° to 103° F., with general aching pains in the back and limbs, with very considerable hæmaturia; in these cases dropsy is usually slight, or even absent. The hæmaturia usually subsides in a few days, but is liable to recur, and these recurrences may be associated with recrudescence of the pyrexia. The dropsy is rarely excessive, and it is well marked in the subcutaneous tissue of the face, loins, and legs, and is often accompanied by ascites. In a few cases the ascites is so great as to require paracentesis; a characteristic feature of the dropsy is the rapid way in which it usually subsides provided the patient is in bed and under treatment. Hydrothorax also occurs, and pulmonary œdema, with or without uræmia, is not infrequent. Dyspnœa and bronchitis are very commonly present, but inflammatory complications, such as pleurisy, pneumonia, and pericarditis are exceptional. Sudden uræmic complications, especially epileptiform seizures, are frequent and often very severe, and, in view of the severity of these seizures, it is remarkable that they are so rarely fatal. Vomiting is often a troublesome symptom difficult to relieve. The uræmic attacks are generally associated with high tension, and often with a sudden increase in the blood pressure, and this is often accompanied with severe headache, which may thus be a warning signal of the imminence of an epileptiform seizure.

Anæmia is generally present only to a slight degree, and it is exceptional for cases to present the well known pallor and waxy appearance so characteristic of renal disease. Marked changes in the fundus oculi are rare in the earlier stages of the malady, but retinitis similar to that seen in chronic renal disease has been described in a proportion of the cases that ran a prolonged course. Retinal hæmorrhage, however, is rare.

The blood pressure is generally raised, and often presents considerable diurnal variations in the majority of cases. There is a great and rather sudden fall in the pressure with the subsidence of the dropsy and the re-establishment of the urinary flow. In the great majority of cases the duration of acute symptoms, and especially the dropsy, is short, *i. e.*, 10 to 14 days; in others it is more prolonged, and in some the dropsy may persist for many weeks.

The urine is diminished in amount, and, during the earlier stages of the disease, the quantity may be about 20 ounces or less in the 24 hours. In severe cases, the amount secreted may diminish still more, and temporary complete suppression is not very rare. Blood

is generally present in small quantity, but, as already mentioned, there is a group of cases where large quantities of blood are found in the urine. The hæmaturia, when slight, is apt to be very persistent, and to continue even when diuresis is fully established. The amount of albumen varies greatly from a mere trace, only present for a few days, to extremely large amounts. Casts, hyaline, granular and epithelial, are usually present. The albuminuria usually lasts much longer than the dropsy, and is apt to return when the patient first gets up.

Prognosis.—The mortality of the disease is very low during the early acute stage, notwithstanding the frequent severity of the uræmic seizures; in a large series of such cases observed in 1915–16 it was 0.4 per cent. Some foreign statistics have yielded a higher rate, *i. e.*, 2.8 per cent., but these included cases observed not only during the acute stage but also subsequently. The dropsy usually clears up with marked diuresis in about a fortnight, but the albuminuria is much more persistent. Death may occur from uræmia or from pulmonary œdema, or other pulmonary complications, or in rare instances from cerebral hæmorrhage. Cases may relapse during convalescence if exposed to unfavourable conditions, and the disease may undoubtedly recur in some cases where, after evacuation to England and a period of regained health, the men have returned to duty with the armies, and then suffered from a recurrence, with a return of all the original symptoms and signs.

Diagnosis.—This does not, as a rule, present any difficulty, but care should be taken to separate from acute nephritis, cases of exacerbation of chronic but latent renal disease, and also cases where the nephritis is not really primary but secondary to some other disease such as bronchitis and broncho-pneumonia. In a certain number of cases nephritis occurs as a complication of infected wounds, and more especially of wounds with streptococcal infections. In rare instances nephritis may be an initial manifestation of cerebro-spinal meningitis, and there may be some difficulty in determining by clinical examination, alone, whether uræmia or meningitis is present; lumbar puncture will decide.

Treatment.—During the acute stage, a milk diet is the most suitable. In some cases a diet consisting largely of vegetables, fruit and bread and butter may be given. Diuretics are not generally suitable but in cases where the dropsy does not subside, caffein or theocin may be given for short periods. Sweating should be encouraged espe-

cially by the use of hot air baths. Moderate purgation especially with saline purgatives is useful. In cases of uræmia venesection is of great value especially when epileptiform seizures are present. Venesection practised during the prodromal stage when headache and high tension are present may prevent the occurrence of actual fits. After the subsidence of the dropsy an increasing diet and tonics should be given. Patients should not be evacuated to England until the subsidence of dropsy. Care should be taken that men are not returned to duty so long as the urine contains albumen together with casts, where this condition of the urine is known to be the result of a recent attack of nephritis.

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